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CAPSICUM & EGGPLANT NEWSLETTER

No. 23

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UNIVERSITY OF TURIN
DI.VA.P.R.A.
PLANT GENETICS AND BREEDING

EUCARPIA

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SCIENTIFIC COMMITTEE

FOREWORD

A last farewell

Dear colleagues, collaborators and readers,

I'm sorry to tell you that this will be the final number of *Capsicum and Eggplant Newsletter*. The initiative begun 23 years ago, following the constitution of the group *Eucarpia* born during the Turin Congress of 1971, and now comes to an end.

The decision was taken after thorough discussion within the Turin group and within the Capsicum and Eggplant section of Eucarpia during a recent meeting in The Netherlands (Noordwijkerhout, May 2004).

The problem is neither a financial one nor the lack of commitment of time and effort required to produce the publication, although both these factors carry some weight. It is the usefulness of the Newsletter itself (like many of its kind) that seems to be fading as the speed and simplicity of international communication and data access increase.

Year by year we see that southern nations are catching up with northern ones in their electronic access to scientific innovation. In consequence, the slow pace of print can now be acceptable only for scholarly and definitive publications; there is no longer a niche for preliminary data or updates published on paper, since these are more quickly and cheaply handled through the net, on websites or by email.

Let us not be sad about this situation because indeed it seems very positive that communication among scientists is globalizing. On the other hand we are happy to have contributed for over twenty years to maintaining lively contact and exchange between pepper and eggplant geneticists worldwide.

I would like to thank all our readers and collaborators who have sent in their contributions, and also our nine committee members. Particular thanks are due to Piero Belletti who, with enormous commitment and enthusiasm, has over all these years undertaken the far from easy job of editing.

Luciana Quagliotti

Dear Readers,

Just a few words to say good-bye to all of you. Prof. Quagliotti has clearly explained the reasons of our decision to stop the publication of the "Capsicum and Eggplant Newsletter." I fully agree with her, and want to say I will remember with pleasure these 23 years spent editing our journal. Indeed it has been an arduous task, but I really hope was useful. If any researcher has gain knowledge or useful information from reading the Newsletter, I believe that our efforts have not been in vain. On the other hand, the world is changing very quickly, and we need to understand the change and adapt our activities to new situations, even if this means a radical change in our habit.

I would like to express how grateful I am to the people I have worked with during these years: firstly to the Members of the Scientific Committee, and also to all of the people who have sent their contributions to the "Capsicum and Eggplant Newsletter." A particular thanks to Paul Bosland, who has always answered quickly and enthusiastically to my (numerous) help requests.

I really hope that the "Capsicum and Eggplant Newsletter" will not cease, but continue on in some mannter. It is possible that others will accept the task to continue the journal, even though it may have different characteristics as compared to the original one. If the "Capsicum and Eggplant Newsletter" is published by someone else, this information will be published on the Internet page of the journal. You are invited to continue visiting the home page of the "Capsicum and Eggplant Newsletter" to keep up with new ideas.

Piero Belletti

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INFLUENCE OF MATURITY AT HARVEST ON CAPSAICIN AND ASCORBIC ACID CONTENT IN HOT CHILLI (*CAPSICUM CHINENSE* JACQ.)

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INTRODUCTION

Capsicum chinense Jacq. is one of the preferred (hot) chilli species grown in the homesteads of Kerala State, India, having a wide range of variability. Pungency is considered as the most important quality trait in chilli. Capsaicin, the pungent principle of chilli, is a condensation product of 3-hydroxy,4-methoxy benzylamine and decylenic acid. Capsaicin has significant physiological action and is used in many pharmaceutical and cosmetic preparations. The green chilli fruits are valuable on account of their richness in ascorbic acid. Maturity at harvest is an important factor affecting the content of capsaicin and ascorbic acid in chilli fruits. Fixing the maturity stage for high capsaicin and ascorbic acid content would be helpful in deciding proper harvesting stage for increasing the quality of the produce.

MATERIALS AND METHODS

This experiment was carried out at the College of Agriculture, Kerala Agricultural University, Thiruvananthapuram, Kerala, India, during 2002 –2003. The study was taken up on ten selected high yielding *C. chinense* genotypes (Table 1). The experiment was laid out in factorial RBD with 30 treatments and three replications. The plot size was 6.75 m^2 with 15 plants planted at 75 x 60 cm spacing. The crop was raised under irrigated condition adopting all recommended cultivation practices. Five plants were selected randomly from each genotype and their capsaicin and ascorbic acid content were estimated at three stages of maturity *viz.*,

M_1 (colour changing stage)	:	Mature fruits just start changing their colour from green to intermediate stage
M_2 (red ripe stage)	:	Fruits become fully ripe, but are firm and succulent in nature
M_3 (withering stage)	:	Fully ripe fruits become shriveled in appearance

Capsaicin content was estimated by Folin-Dennis method. The pungent principle reacts with Folin-Dennis reagent to give a blue coloured complex which is estimated colorimetrically (Mathew *et al.*, 1971). Ascorbic acid content was estimated by 2,6-dichlorophenolindophenol dye method (Sadasivam and Manickam, 1992).

RESULTS AND DISCUSSION

Analysis of variance for capsaicin and ascorbic acid content over different maturity stages showed that maturity x genotype interaction was significant (Table 2).

Significant variation was observed among genotypes for capsaicin content at colour changing stage (1.26 to 3.02 %), at red ripe stage (1.32 to 3.18 %) and at withering stage (1.48 to 3.36 %).

The genotype CC 3 had maximum capsaicin content of 3.02, 3.18 and 3.36 per cent respectively for colour changing, red ripe and withering stages. Genotype CC 23 recorded minimum capsaicin content at colour changing, red ripe and withering stages (1.26, 1.32 and 1.48 % respectively).

Ahmed *et al.* (1987) tabulated the capsaicin content at three different stages *viz.*, green, ripe and sun dried fruits of twelve *C. annuum* varieties. According to them capsaicin content increased in the order green fruit < ripe fruit < sun dried fruit. Estrada *et al.* (2000) studied changes in capsaicin with fruit development in *C. annuum* and observed that capsaicinoid increases with fruit development. Narayanan *et al.* (1979) reported that capsaicin content increased steadily from green fruit stage to dry pod stage. Kweon *et al.* (2002) analysed hot pepper (*C. annuum*) cultivars during different ripening stages and found that capsaicin content was highest at the third ripening stage.

In general, the genotypes recorded highest capsaicin content at withering stage, moderate at full ripe and lowest at colour changing stage. The results of Balbaa *et al.* (1968) and Mini (1997) support the present study.

Capsaicin is synthesized and accumulated in capsaicinoid secreting cells in placenta. The site of capsaicin synthesis and total capsaicin content are genetically controlled. As the fruit matures, placenta also gets matured and capsaicin content increases. At withering stage, moisture content of the fruits may get reduced when compared to colour changing stage and thus the percentage of capsaicin increases.

Chillies are the richest plant source of ascorbic acid. A wide variation in ascorbic acid content was observed in the different stages of maturity. It ranged from 89.40 to 130.12 mg/100 g fresh fruit at colour changing stage, 95.23 to 136.45 mg/100 g fresh fruit at red ripe stage and 89.26 to 136.59 mg/100 g fresh fruit at withering stage.

Ascorbic acid content was maximum for genotype CC 7 at colour changing, red ripe and withering stages (130.12, 136.45 and 136.59 mg/100 g respectively) and minimum for genotype CC 11 at colour changing, red ripe and withering stages (89.40, 95.23 and 89.26 mg/100 g respectively).

In general, the genotypes had maximum ascorbic acid content at red ripe stage than at other stages. There is a continuous increase in the ascorbic acid content of chilli fruits up to red ripe stage and then it declines towards withering stage.

This result is in agreement with Lalithakumari *et al.* (1999) and Gnayfeed *et al.* (2001) who reported in *C. annuum* that as ripening advanced, the ascorbic acid content reached its maximum towards the red ripe stage and then it declined. The ripened fruits contained higher ascorbic acid content than mature green fruits. With the advent of drying of ripened fruits, ascorbic acid content declines due to various biochemical changes occurring during drying.

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Table 1 Source of selected genotypes in Capsicum chinense

Sl. No.	Genotype	Source*	Sl. No.	Genotype	Source*
1	CC 23	Nemom	6	CC 30	Nemom
2	CC 13	Vithura	7	CC 28	Pothencode
3	CC 7	Vithura	8	CC 31	Nemom
4	CC 2	Anchal	9	CC 3	Neyyatinkara
5	CC 15	Vilavoorkal	10	CC 11	Vithura

* All genotypes are from Thiruvanathapuram district except CC 2, which is from Kollam district of Kerala State, India

Table 2 Mean performance of genotypes for capsaicin and ascorbic acid content over different maturity stages

Genotype	Capsaicin (%)				Ascorbic acid (mg / 100 g fresh weight)			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
CC 23	1.26	1.32	1.48	1.35	95.23	101.18	95.23	97.21
CC 13	2.54	2.73	2.80	2.69	95.23	100.18	106.31	100.57
CC 7	2.30	2.52	2.68	2.50	130.12	136.45	136.59	134.38
CC 2	2.12	2.68	2.50	2.43	101.18	101.18	95.23	99.20
CC 15	1.49	1.61	1.88	1.66	101.18	106.92	105.77	104.62
CC 30	2.18	2.40	2.44	2.34	95.23	101.18	95.23	97.21
CC 28	2.10	2.57	2.65	2.44	101.18	107.12	107.12	105.14
CC 31	2.06	2.24	2.38	2.22	113.97	118.68	113.33	115.33
CC 3	3.02	3.18	3.36	3.19	118.01	124.40	124.74	122.38
CC 11	2.65	2.86	2.95	2.82	89.40	95.23	89.26	91.30
Mean	2.17	2.41	2.51	2.36	104.07	109.25	106.88	106.74

CD values

Genotype	0.02	Genotype	1.39
Maturity	0.01	Maturity	0.76
Genotype x Maturity	0.04	Genotype x Maturity	2.41

Capsicum and Eggplant Newsletter 23 (2004): 17-20.

NOVEL CAPSAICINOID LIKE SUBSTANCES IN THE FRUITS OF NEW NON-PUNGENT CULTIVAR 'CH-19 Sweet' OF PEPPER (*Capsicum annuum*)

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INTRODUCTION

Capsaicin is the main compound of pungency in pepper fruit and has physical activities for the human body. Capsaicin homologs are called capsaicinoid. It is possible to utilize capsaicinoid as food additive and in medicine, but strong pungency limits the use of capsaicinoid. In 1979, Yazawa introduced a hot pepper 'CH-19 Pungent' from Thailand and produced the original non-pungent pepper by selfing and selection of 'CH-19 Pungent' and named it 'CH-19 Sweet'. Yazawa found that 'CH-19 Sweet' fruit is little pungent, but contains capsaicinoid like substances (CLSs, tentatively named CLS-A, CLS-B). Kobata *et al.* (1998) found that CLS-A is a vanillyl alcohol and CLS-B is a capsaicin analog. CLS-B was named capsiate. A putative capsiate biosynthetic pathway is shown in Fig. 1 (Watanabe *et al.*, unpublished).

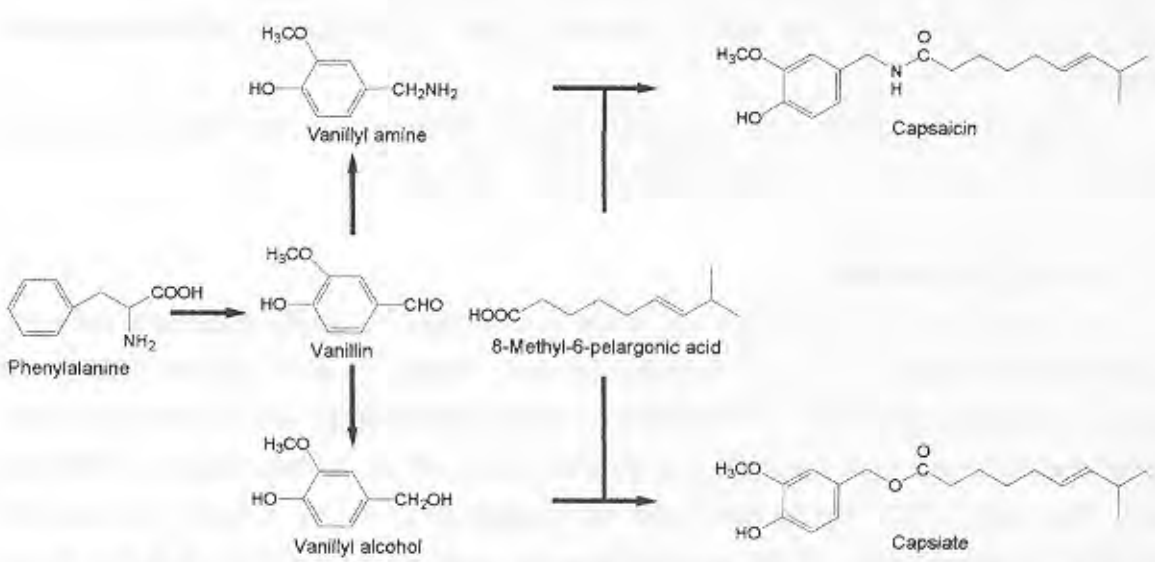

Fig. 1 Putative capsiate biosynthetic pathway (Watanabe *et al.*, unpublished)

Capsiate homologs in 'CH-19 Sweet' fruit were isolated, named dihydrocapsiate, nordihydrocapsiate and the compoud group was named capsinoid. Like capsaicinoid, capsinoid were reported to increase body temperature in mice and human (Ohnuki *et al.*, 2001). Capsinoid are non-pungent so that it may be possible to utilize a considerable amount of capsinoid for food and drug applications. In this experiment we investigated the capsinoid content of some capsicum cultivars and selected 'CH-19 Sweet' in which the capsinoid content was high.

MATERIALS AND METHODS

Some capsicum cultivars (shown in Tab. 1) were used in this experiment. Capsaicinoid and capsinoid content of pepper fruit was determined using TLC and HPLC.

Thin Layer Chromatography (TLC) analysis: Fruit was freeze-dried and ground to a powder. 1.5-2.0 g of powder was extracted with acetone and ethyl acetate. The extracts were chromatographed on a silicagel G plate by using two kinds of solvents, chloroform : methanol : 28% ammonia water (95 : 5 : 0.5(v/v)) as the first eluent and toluene : chloroform : acetone (40 : 35 : 25(v/v)) as the second. The isolation of capsaicinoid and capsinoid was performed on HPTLC plates RP-8 F 254s (Merck) by using 0.05M silver nitrate, 0.05M boric acid in 85% methanol as eluent. After development, capsaicinoid and capsinoid were detected by spraying 2,6-dichloroquinone-4-chloroimide (0.1%) solution dissolved in 85% methanol in an atmosphere of gaseous NH_3. The content of capsaicinoid and capsinoid were determined using a dual wavelength flying spot scanning densitometer (SHIMADZU, CS910).

High Pressure Liquid Chromatography (HPLC) analysis: Fruit was freeze-dried and ground to a powder using a coffee mill (MK-51M, MATSUSHITA). 0.2 g of powder was extracted with acetone and ethyl acetate. An aliquot was then injected into a HITACHI HPLC and the samples developed on μ Bondapak C-18 reverse phase columns (Waters, 10 μ m 3.9 $\times$ 150mm) detected at 280 nm. The elution (Methanol/water, 70/30) was run at the flow rate of 1.0 ml/min.

In order to produce high capsinoid content peppers, we have tried to fix high capsinoid content in 'CH-19 Sweet' fruit by selfing and selection.

RESULTS AND DISCUSSION

We determined capsaicinoid and capsinoid content in some capsicum cultivars. Capsaicinoid and capsinoid content of some cultivars, 'Yokaku', 'Gosiki', 'Enomi', 'Cayenne long slim', 'Hungarian yellow wax', 'Puchi marble', was determined by TLC. Capsaicinoid and capsinoid content of the other peppers was determined by HPLC. Sweet peppers, 'California wonder', 'Murasaki', 'Shishitoh', contained no capsinoid (Tab. 1). Some hot cultivars 'Aroma-Af3', 'Takanotsume', 'Gosiki' etc. contained a small amount of the capsinoid and a large amount of the capsaicinoid (Tab. 1). As shown in Fig.1, it is considered that the

capsinoid biosynthetic pathway is closely related with the capsaicinoid biosynthetic pathway. Capsaicinoid biosynthetic pathway does not exist in sweet peppers so that sweet peppers contain no capsinoid. Only 'CH-19 Sweet' contained a small amount of the capsaicinoid and a large amount of the capsinoid (Tab. 1). 'CH-19 Sweet' seemed to be most suitable for producing the capsinoid.

High capsinoid content of 'CH-19 Sweet' fruit is desirable. We have selected and selfed a progeny that contains a large amount of capsinoid from 'CH-19 Sweet'. By 1998, capsinoid content of 'CH-19 Sweet' fruit was under 3000 μ g/gDW. From 1999 capsinoid content was raised over 7000 μ g/gDW. By repeating selection of 'CH-19 Sweet', the capsinoid content in the fruits increased 80 times (Fig. 2).

Tab. 1 Capsaicinoid and capsinoid content among some capsicum cultivars

Cultivar				Capsaicinoid content (μg/gDW)	Capsinoid content (μg/gDW)
'CH-19 Sweet'	*C.annuum*	(Japan)	(H)	n.d.	1818
'Nikko'	*C.annuum*	(Japan)	(H)	230	159
'Takanotsume'	*C.annuum*	(Japan)	(H)	2204	155
'Tsumura'	*C.annuum*	(Japan)	(H)	11517	40
'Yokaku'	*C.annuum*	(Japan)	(T)	1511	51
'Gosiki'	*C.annuum*	(Japan)	(T)	4238	131
'Enomi'	*C.annuum*	(Japan)	(T)	9197	73
'Cayenne long slim'	*C.annuum*	(USA)	(T)	1136	79
'Hungarian yellow wax'	*C.annuum*	(USA)	(T)	870	9
'Habanero'	*C.chinense*	(Mexico)	(H)	20069	37
'Af-8'	*C.baccatum*	(Cote d'Ivoire)	(H)	5290	52
Yatsuhusa'	*C.annuum*	(Japan)	(H)	3602	82
'Puchi marble'	*C.annuum*	(USA)	(T)	n.d.	12
'Aroma-Af3'	*C.chinense*	(Rwanda)	(H)	2737	1106
'Sy-2'	*C.chinense*	(Seychelles)	(H)	5170	710
'California wonder'	*C.annuum*	(Japan)	(H)	n.d.	n.d.
'Murasaki'	*C.annuum*	(Japan)	(H)	n.d.	n.d.
'Shishitoh'	*C.annuum*	(Japan)	(H)	n.d.	n.d.

n.d.:not detected
T:by TLC, H: by HPLC

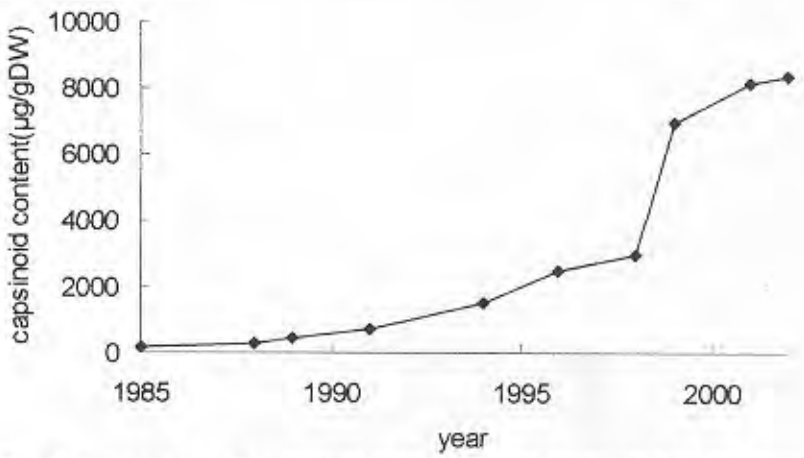

Fig. 2 Increasing of capsinoid content in the fruits of 'CH-19 Sweet' lines

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EVALUATION OF SWEET PEPPER ASSORTMENT *(CAPSICUM ANNUUM L.)*

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INTRODUCTION

In the years 2001-2003 significant properties of pepper assortment were studied. In experiments we studied chosen biological, morphological and technological quality of vegetable pepper assortment.

MATERIAL AND METHODS

Sweet pepper material (19 varieties) were grown under plastic tunnels or in field trials by methods VALŠÍKOVÁ et al (1996) and STŘELEC, (1975). The varieties of sweet pepper we evaluated by Descriptors for Capsicum (COLLECTIVE, 1995). The results are showed in tables 1-3.

RESULTS

Documentation of origin, breeding place, year of registering in SR, suitability for growing of varieties is noticed in table 1. Data about duration of vegetation period, fruits shape, number of locules and fruit wall thickness are in table 2. Size of pepper fruits is expressed by data about length and width of fruits in years 2001 – 2003 and their average value. The longer fruits (between 116,20 and 163,96 mm) had varieties *'Amy'*, *'Fok'*, *'Imelská'*, *'Lumina'*, *'Lýdia'*, *'Nesvadská'*, *'Plameň'* and *'Slovakia'*. The biggest average fruit width had variety *'Imelská'*(82,23 mm),, *'Merišor'*, (83,46 mm), *'Amy'* (71,00 mm), and *'Nesvadská'* (70,70 mm). We have evaluated the ascorbic acid in green fruits and red fruit as well (KRÁLOVÁ, VALŠÍKOVÁ, 2003). Average contents of ascorbic acid in green fruits during following period was highest at variety *'Maryša'* (21,59 mg.1000g^{-1}), *'PCR'* (20,35 mg.1000g^{-1}) and *'Rubinova'* (20,13 mg.1000g^{-1}). The lowest ascorbic acid content in green pepper they had variety *'Slovakia'* (15,15 mg.1000g^{-1}), *'Golde'* (15,62 mg.1000g^{-1}) and *'Citrina'* (15,86 mg.1000g^{-1}). In red fruits reached the highest ascorbic acid content varieties *'Lydia'* (30,40 mg.1000g^{-1}), *'Amy'* (30,06 mg.1000g^{-1}) and *'Granova'* (29,89 mg.1000g^{-1}). The average contents of ascorbic acid in green fruits was highest in year 2003 19,76 mg.1000g^{-1}). In red fruits was highest average ascorbic acid content in year 2002, namely 27,59 mg.1000g^{-1}.

In tested assortment varieties *'Imelská'*, *'Nesvadská'*, *'PCR'*, *'Fok'*, and *'Plameň'* are pungent. The rest varieties are sweet (Tab. 3). The highest average weight reached varieties *'Imelska'* - 136,83 g, *'Nesvadská'* 131,00 g and *'Lýdia'* - 125,76 g. Least average weight had variety *'Fok'* - 46,10 g, *'Almapaprika'* - 55,63 g and *'Plameň'* - 70,20 g.

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Table 1.

Variety	Origin	Breeding place	Year of registration in SR	Suitability for growing
Almapaprika	HU	Szentesi Mag Szentes	1998	FL
Amy	CZK	Semo Smržice	1996	PT
Andrea	SK	ŠS Kvetoslavov	1987	PT, GR, FL
Citrina	SK	ŠS Kvetoslavov	1977	FL
Fok	MD	VÚ Tiraspol	Unregistered	FL
Golde	SK	ŠS Kvetoslavov	1995	FL
Granova	SK	ŠS Kvetoslavov	1987	FL
Imelská	SK	VÚZ Nové Zámky	2001	PT, GR
Lumina	MD	VÚ Tiraspol	Unregistered	PT, FL
Lýdia	CZK	Semo Smržice	1996	PT, FL
Maryša	CZK	ŠS Čejč	1993	FL
Merišor	MD	VÚ Tiraspol	Unregistered	PT, FL
Nesvadská	SK	VÚZ Nové Zámky	2003	PT
PCR	SK	ŠS Kvetoslavov	1967	PT, GR
Plameň	MD	VÚ Tiraspol	Unregistered	FL
Rubinova	SK	ŠS Kvetoslavov	1988	FL
Slovakia	SK	ŠS Králová pri Senci	1995	FL
Zlata	SK	ŠS Kvetoslavov	1990	FL
Zorka	CZK	ŠS Čejč	1994	FL

Comment:
SK - Slovakia
CZK - Czech republic
HU - Hungary
MD - Moldavia
PT – Plastic tunnel
GR - Greenhouse
FL - Field

Table 2.

Variety	Maturity	Fruit shape	Number of locules	Flash thickness (mm)
Almapaprika	medium	almost round	2 - 3	9,0
Amy	medium	conical	3 - 4	6,0
Andrea	medium late	tapered	3	8,0
Citrina	early	conical or blocky	3	8,0
Fok	medium	conical	2 – 3	7,0
Golde	medium	blocky	3 - 4	6,0
Granova	medium late	blocky	3	7,0
Imelská	medium	tapered	3	6,0
Lumina	medium	conical	3	8,0
Lýdia	medium	conical	2 - 3	4,0
Maryša	medium	conical	3 - 4	8,0
Merišor	medium	triangular	2 - 3	9,0
Nesvadská	medium	tapered	3	5,0
PCR	early	conical	2 - 3	5,0
Plameň	medium	conical	3	6,5
Rubinova	early	conical	2 - 3	8,0
Slovakia	very early	conical	3	6,0
Zlata	medium	conical	2 - 3	6,0
Zorka	medium	conical	3 - 4	6,0

Table 3.

Variety	Fruit colour		Fruit taste in physiological maturity	Fruit weight (g)			
	In technical maturity	In physiological maturity		2001	2002	2003	Average
Almapaprika	light green	light red	sweet	49,20	58,30	59,40	**55,63**
Amy	white yellow	light red	sweet	114,00	118,50	120,60	**117,70**
Andrea	yellow green	light red	sweet	78,80	88,60	92,10	**86,50**
Citrina	yellow green	light red	sweet	87,80	96,30	98,70	**94,26**
Fok	light green	light red	very pungent	45,00	47,10	46,30	**46,10**
Golde	yellow	Red	sweet	128,00	121,80	120,60	**123,46**
Granova	green	light red	sweet	113,00	115,80	117,60	**115,46**
Imelská	light green	Red	pungent	134,00	137,40	139,10	**136,83**
Lumina	yellow green	light red	sweet	110,00	118,00	120,30	**116,10**
Lýdia	yellow green	light red	sweet	121,00	127,10	129,20	**125,76**
Maryša	light green	Red	sweet	98,70	100,80	102,60	**100,70**
Merišor	light green	deep red	sweet	83,60	89,30	91,70	**88,20**
Nesvadská	light green	Red	middle pungent	126,00	132,40	134,60	**131,00**
PCR	light green	Red	pungent	83,90	98,80	96,50	**93,06**
Plameň	dark green	Red	very pungent	68,00	72,00	70,60	**70,20**
Rubinova	green	deep red	sweet	98,70	100,80	101,60	**100,36**
Slovakia	light green	Red	sweet	118,00	122,00	123,10	**121,03**
Zlata	yellow	light red	sweet	89,90	94,10	93,70	**92,56**
Zorka	light green	Red	sweet	96,80	99,50	101,70	**99,33**
Average				**97,07**	**102,03**	**103,15**	

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CHARACTERIZATION OF LOCAL PEPPER LINES FROM NORTHWEST SPAIN

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SUMMARY:

Eighteen local pepper (*Capsicum annuum*) lines from Northwest Spain were evaluated at Mabegondo (A Coruña) on 2002. These lines showed a great variation in morphological traits. Principal component analysis was carried out to identify clusters of morphological and agronomical homogeneous behaviour. A hierarchical clustering method on the first three components was used to separate four different groups (72 % of variance explained). Each cluster was described by the means of the different traits and compared with other clusters. The great variation within lines was no obstacle for the distinction of the two types of pepper (Couto and Padrón). The higher variability in traits was observed within the "Couto" type lines. Fruit characters have a higher weight in the characterization than other morphological characters.

INTRODUCTION:

The "Padron" peppers are local hot pepper cultivars brought to the northwest of Spain on the XVII century, with short triangular fruits (Nuez *et al*, 1998; Estrada *et al*, 2000). This type of peppers is not only produced on the northwest of Spain and is very appreciated by the spanish consumers. The "Couto" pepper is a local ecotype cultivated on the province of A Coruña, very similar to the Padrón type with a longer non hot fruit (Carreiras, 1997).

Studies about *Capsicum* germplasm from the Northwest of Spain have only been reported by Nuez *et al* (1998), there are other authors that study some physiological aspects of "Padrón" type peppers (Estrada *et al*, 1998, 1999 and 2000). Local *Capsicum* collections are also being studied in other parts of Spain (Casquero & Guerra, 2000; Nuez et al, 1998).

The great variability between the local cultivars of *Capsicum annuum* in the Northwest of Spain, either within the "Couto" (Carreiras, 1997) or the "Padrón" type (Estrada *et al*, 2000) is the main reason of the morphologic and agronomic evaluation of 18 local lines presented in this work. It would be interesting to complete the description of *Capsicum* local lines grown in Northwest Spain and to identify lines from this area with desirable characters useful for Capsicum improvement. The characterization presented here forms part of the Breeding Program of the Couto pepper, actually being carried out at the Centro de Investigaciones Agrarias of Mabegondo.

MATERIALS AND METHODS:

Eighteen local lines of *Capsicum annuum* were evaluated at the Northwestern Spain on 2002. The site was located at: (1) Mabegondo (43° 15'N, 8° 18'W) near the coast.

Thirteen of the eighteen lines belonged to the Couto type and were obtained at the Centro de Investigaciones Agrarias de Mabegondo during 1998 and 1999, the rest of the lines were Padrón type and selected at the Centro de Experimentación de Baixo Miño from 1995 to 1999.

All the lines were sown in february 2002 in greenhouse, the seedlings were then trasplanted to a plastic greenhouse. Plots (0,4m x 0,8 m) were laid out in a randomized block design with three replications and 12 plants per replication, and these were fertirrigated weekly by means of a drip irrigation system. The following measurements were recorded on every plant of each replication the sixth week after transplanting them: plant height, cross height, number of arms and stem diameter. At the stages of ripe fruits (red fruits) the following measurements were recorded on each of the 10 fruits randomly collected in each line at the two locations: weight, length, width, pedicel length, number of loculus, flesh thickness and placenta length.

Early plot yield (accumulated of the first four weeks of production) and total yield was also determined.

An analysis of variance of these traits was made using the following model for data from individual plants:

$$X_{ij} = M_u + b_i + g_j + (b*g)_{ij} + E_{ijk}$$

Where: M_u is the overall average, b_i is the block effect, g_j is the line effect, $(b*g)_{ij}$ is the block*line interaction and E_{ijk} is the residual (i.e. within plot) effect. The block effect was considered a random effect.

Data from fruits were analysed using the model: $X_{ij} = M_u + g_j + E_{ijk}$.

Yield data from plots were analysed using the folllowing model: $X_{ij} = M_u + b_i + g_j + E_{ijk}$.

Multivariate relationships among lines were revealed with a principal component analysis (PCA) using a correlation matrix derived from the significant traits after the analysis of variance. The components with eigenvalues greater than one were used through hierarchical clustering analysis based on Euclidean distance computed between each population. The dendogram formed by this method was cut at the four level cluster, each cluster being represented on the Principal Component Plan 1-2.

RESULTS AND DISCUSSION:

Means, range of variation and principal results of the ANOVA are in Table 1. Most of the characters presented a very significant line effect except stem diameter, early and total yields, fruit flesh length as well as fruit number of loculi. Consequently , we will consider in this paper each line to be characterised by the eight significant characters: line means of these traits.

Table 2 .-Correlations between initial characters measured and the first two axes of a principal component analysis on a correlation matrix.

	Axis 1	Axis 2
P. height	**0.3864**	0.2277
Cross h.	**0.3946**	0.0713
N° arms	**0.3074**	- 0.0211
F. length	- 0.2656	**0.5833**
F.width	**0.4338**	0.0204
F. weight	0.3856	0.2009
Pedicel length	**0.4306**	0.0539
Placenta length	- 0.086	**0.7474**
Eigenvalue	4.3865	1.3867
% Ac. Variance	54.83	72.17

Principal component analysis is used frequently to summarise large amounts of data. The first plan of the PCA explained the 72.17 of the total variance. The first axis can be interpreted as an axis related with plant characters (plant and cross height as well as number of arms). Axis 2 is explained by fruit characters like fruit width or pedicel length. The projection of each line on the plan defined by Axis 1 and 2 are presented on Figure 1. Different lines are coded with numbers.

Table 1 – Mean, range of variation and main results of the ANOVA of morphologic and agronomic characters for 18 local pepper cultivars at Mabegondo

	Mean	Range	Block	Lines	Block*Line
Plants					
Height (cm)	108.4	87.5 – 126.3	***	***	***
Cross height (cm)	22.38	16.4 – 32.9	NS	***	NS
N° arms	2.55	2 – 3	NS	***	NS
Stem diameter (cm)	13.18	12.2 – 15.6	***	NS	***
Yields					
Early yield (g)	1771.38	1076.4 – 2348.6	NS	NS	
Total yield (g)	8162.3	5251 – 10074	NS	NS	
Fruits					
Length (cm)	8.211	6.75 – 9.63		***	
Width (cm	2.588	2.02 – 3.25		***	
Weight (g.)	15.88	10.6 – 30.8		***	
Pedicel length (cm)	2.429	1.95 – 3.23		***	
Flesh thickness (cm)	0.207	0.16 – 0.24		NS	
Placenta length (cm)	2.101	1.75 – 2.53		***	
N° loculus	2.72	2 – 3		**	

*, **, ***= significant at 0.05, 0.01 and 0.001 level respectively. NS – not significant.

Figure 1 .- Projection of 18 local lines of *Capsicum annuum* (1-18) on the plan 1-2 of a principal component analysis carried out on a correlation matrix on morphologic and agronomic traits. Accumulated variance = 72.17 %.

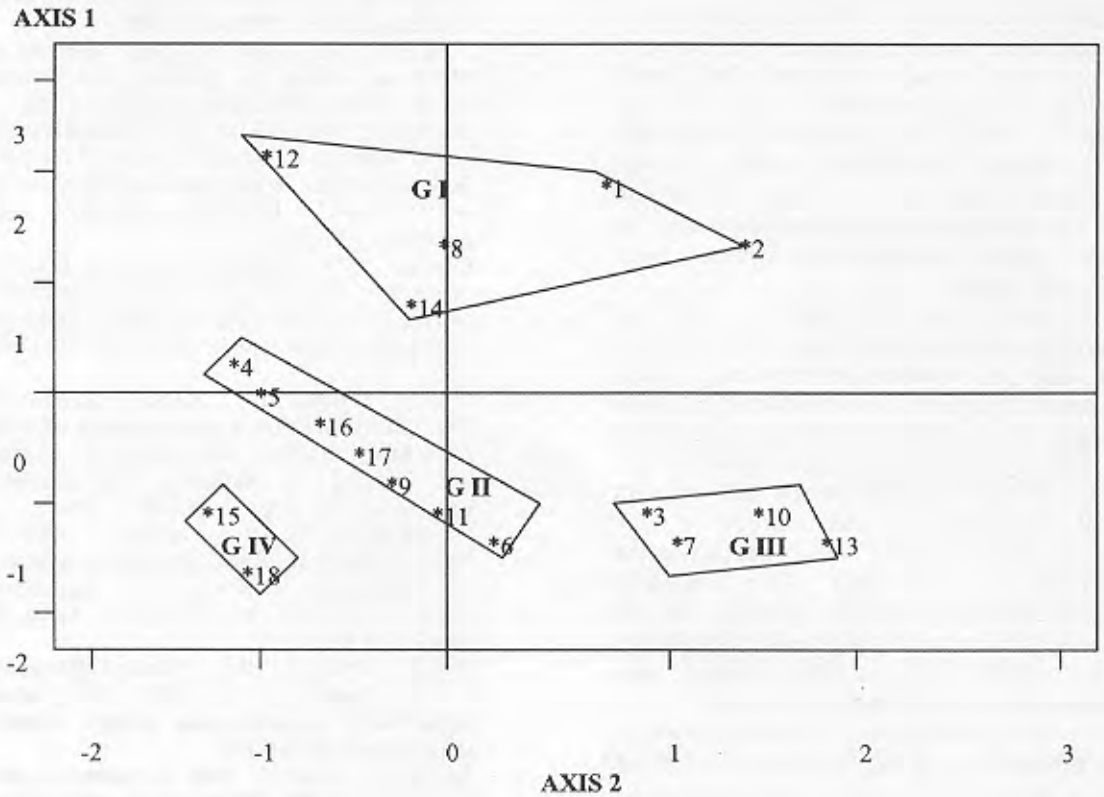

Table 3 . Means of the different groups obtained from the ascendent hierarchical classification. Means in the same line following the same letter are nor significantly different from each other based on Duncan´s multiple range test at P=0,05.

Groups		I	II	III	IV
Plants					
	Height (cm)	128.82 a	106.40 b	96.92 c	99.36 c
	Cross height (cm.)	30.88 a	18.48 b	19.39 b	18.93 b
	N° arms	2.74 a	2.52 b	2.41 b	2.44 b
Fruits					
	Length (cm.)	7.39 c	8.14 b	9.47 a	7.95 b
	Width (cm.)	3.12 a	2.48 b	2.39 b	2.04 c
	Weight (g.)	19.30 a	14.91 b	15.94 b	10.66 c
	Pedicel length (cm.)	2.91 a	2.27 b	2.32 b	2.02 c
	Placenta length (cm.)	2.01 b	2.09 b	2.39 a	1.77 c

An ascendent hierarchical classification carried out on the base of Euclidean distances obtained from the coordinates of the first three axes of the PCA allowed the lines to be regrouped in classes of a similar behaviour. A partition was chosen in four groups and 72 % of total variance was explained. The projection of the group number on the plan 1-2 showed that group I included all the "Padron" type lines with short and triangular fruits. Group III gathered the "Couto" type lines with long, pointed and elongated fruits. Group IV included the "Couto" type lines with short triangular fruits, similar to the "Padrón" type, and group II gathered "Couto" lines with fruits that had intemediate characteristics between groups III and IV. Means of the different groups are shown in table 3.

Local lines of pepper collected in Northwest Spain, specially "Couto" type, show a wide range of variation, as reported in other publications (Carreiras, 1997; Estrada *et al*, 2000; Rivera & Andrés, 2001). This work of evaluation and the availability of these genetic resources are going to allow the selection of new cultivars, with typical morphological characteritics of the respective type of pepper and adapted to the conditions of the Northwest Spain. The great variation among lines was no obstacle for the distinction of the two types: "Padrón" type lines are all gathered in group I while "Couto" type lines are included on groups II, III and IV.

The results of this evaluation show a great variation in 8 of the 12 studied traits, being most of them fruit characters. The importance of fruit characters – flesh thickness, fruit weight or fruit width - on pepper evaluations has been reported previously by other authors (Cuartero and Pochard, 1977; Costa et al, 1989; Cuartero et al, 1983; Berchez & Dumitrescu, 1995).

It is also important to mention the great variation recorded in characters non related with the fruit such as plant height, cross height and number of arms which may be succesfully used for the distinction of the two types of peppers.

The reduced variation in yield is also an important character for the respective breeding programs. The small variation on the early yield among the "Couto" type lines differs from previous reports (Rivera et al, 2001) and is also a very important character for breeding as pepper prices have important oscilations along the production period.

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GREEN PEPPER GERMPLASM SELECTION FOR IMPROVED PRODUCTION UNDER HEAT AND DROUGHT STRESS CONDITIONS

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ABSTRACT

A bulk collection of green pepper (*Capsicum annuum* L.) land variety from southern Egypt was evaluated under heat and drought stress conditions. Higher percentage of fruit set was positively associated with increased number of fruits, fruit weight and fruit yield while negatively associated with plant height. Elite individual plants were visually selected and their selfed progenies were tested. Parent-offspring regression suggested that non-heritable genetic components of variation had a considerable influence on the expression of percent fruit set, average fruit weight, number of fruits/plant and fruit yield/plant. Population raised using bulked S_2 seeds of two most elite tested progenies showed significant increase in these traits compared with population of the original land variety collection. This developed germplasm selection may be useful for stress breeding and physiology investigations in pepper.

Keywords: abiotic stress, breeding resources, (*Capsicum annuum*), progeny test, selection.

INTRODUCTION

Green pepper is an important nutritious vegetable and its production is usually limited by high temperatures (Takagaki et al., 1995) where flower abscission occurs especially under deficiency of soil moisture. In spite of introducing several new cultivars, substantial amount of green pepper (*Capsicum annuum* L.) in southern Egypt, is currently still produced using a local highly heterogeneous cultivar. Growers use this cultivar due to its adaptation to prevailing environmental conditions in this region. It is also favourable for the local consumers who use its fruits both as fresh vegetable and as pickle. Because of the high per cent of outcross, up to 70, in pepper (George, 1985; Todorov and Csillery, 1990), this cultivar can be considered as a mixture of heterozygous genotypes originated in the past from intervarietal crosses occurred in the grower's farms where they produce their own seeds without adequate isolation and no practising for plant roguing.

The cultivar is produced under conditions of usually low farming inputs, interrupted schedules of irrigation, and temperatures higher than optimum for production of pepper. It may be useful, therefore, to study a collection of this land-variety of pepper towards isolation of beneficial variants for improving pepper production under stressful conditions. The primary objective of the present study was to evaluate the performance of a land-variety collection and both the first and second selfed-generation progenies derived from elite plants screened within it for green fruit yield under heat and drought stress conditions.

MATERIALS AND METHODS

Collection and primary evaluation of original land variety population

Green pepper (*Capsicum annuum* L.) land-variety used in the present study was collected

from different farmers and local seed retailers in Assiut, mid-southern Egypt. Sixty-day old seedlings from this collection of the land variety ('ALV') and also from the sweet bell pepper 'California Wonder' ('CW') (product of Pop Vriend LTD. Holland) were transplanted and grown under stressful heat conditions during late summer planting. The maximum temperature ranged from 36.5 to 41.3°C and night temperature ranged from 20.6 to 29.7°C during the growing of this study at the Agricultural Research Station, Assiut University. The soil in the experimental site was clay loam. It contained 0.6 % total N. Transplanting of the seedlings was 30 cm apart on the northern side of 70 cm wide rows. Starting at the flowering stage of development, the plants were irrigated when 58 to 60% of the available soil water was depleted. The plants were fertilized with 150 kg ammonium nitrate (33.5% N) and 200 kg superphosphate (15.5% P_2O_5) per feddan (4200m^2). Otherwise all cultural practices were as usual for production of green pepper. The experiment was randomized complete-blocks with six replicated. Fifty plants were grown from each of 'ALV' and 'CW' per replicate. Individual plants were used to record the following traits: 1) plant height at maturity, 2) percentage of fruit set, 3) fruit shape, 4) average fruit weight, 5) number of fruits, and 6) fruit yield.

Evaluation of bulked S_2-progeny derived population

At the end of the primary evaluation season, the top fifteen plants from the ALV population were selected based on the percent of fruit set, fruit weight, and number of fruits. Six of these plants were excluded because of their strongly wrinkled and irregular shaped fruits. Shoot-buds in leaf axils (Fig. 1 a) on the 5 to 7 basal stems nodes were excised from the remaining 9 plants. These shoot-bud explants were stirred for 10 sec in 70% ethanol followed by 10 min in 0.5% sodium hypochlorite (10% Clorox plus two drops of Tween-20 per liter). Then they were rinsed three times with sterile distilled water. The disinfested explants were cultured under aseptic conditions on MS (Murashige and Skoog, 1962) medium containing no plant growth regulators (PGRs). The medium contained 3% sucrose and 0.7g/l agar. The pH of the medium was adjusted to 5.7 before being autoclaved (1.5 $kg.cm^{-2}$ at 121°C). The axenic cultures of the explants from each individual plant were kept separate at 25°C±0.5 under light (16h/day) from cool-white fluorescent tubes. Four weeks after incubation, the growing shoot-buds were transferred to the medium with or without 2 µM α-naphthaleneacetic acid (NAA). The rooted shoot-buds were transplanted into 5-cm plastic pots containing sterile mixture of equal volumes from sphagnum peat, washed sand, and soil. These pot cultures were acclimatized under plastic chamber. Two weeks later, acclimatized plantlets were transplanted in the plastic house. These propagated plants were used to produce selfed seeds (S_1) from each of the 9 screened plants.

Subsequently, the S_1 progenies of the 9 selected plants were tested when grown under heat and drought conditions indicated above. The 'ALR' population was also grown. The 10 entries were arranged according to randomized complete-blocks with three replicates. Each replicate contained 40 plants from each S_1 progeny and the 'ALR' population. Three to five flower buds were isolated to produce S_2 seeds from selected plants within each of the 9 S_1 progenies. These plants were chosen based on their ability to set fruits from the first formed 5 to 7 flower buds. Data records were the same as indicated above for the primary evaluation experiment. Based on mean performance of S_1 progenies, bulked S_2 seeds from two progenies were saved for further evaluation under stressful heat and drought conditions. This seed mixture was designated as population HD1-12. Randomized complete-blocks experiment with three replicates was used to evaluate the HD1-12 population with the base landrace population. Forty seedlings were transplanted from each of these populations per replicate. Data were recorded on the plant traits mentioned elsewhere above. All data from the present study were analyzed according to the statistical methods explained by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Pepper plants in the land variety ('ALV') exhibited a wide range of variation in fruit set (0 to 75%) under the heat and drought stress conditions tested in this study. Normal seed set in the fruits of the landrace was observed. In contrast, the bell pepper cv. 'California wonder' (CW) had fruits containing few or no seeds. The percentage of fruit set in this cultivar under these conditions ranged from 0.0 to 20. All fruits produced from the cv. 'CW' were unmarketable due to their small size and misshape. Plants of the cv. 'CW' were significantly ($P < 0.01$) less in plant height than those plants in the 'ALV' (21.4 cm vs 37.8 cm). In the population of 'ALV', higher percentage of fruit set was associated with increased number of fruits ($r = 0.759$, $P<0.01$), fruit weight ($r = 0.156$, $P<0.01$), and fruit yield ($r=0.545$, $P<0.01$). The linear phenotypic correlation coefficient between fruit set per cent and plant height was negative ($r = -0.147$, $P<0.05$).

S_1 progenies of the nine individual plant selections from the 'ALV' showed wide range of variation and also variation was wide within population of each progeny (data not shown). Regression of these progeny means on their corresponding parental means were 0.276±0.544 for percent fruit set, 0.366±0.481 for average fruit weight, 0.034±0.09 for number of fruits/plant and 0.145±0.132 for fruit yield/plant. These results suggest that the screened individual plants were highly heterozygous and non-heritable genetic components of variation had a considerable influence on the expression of these traits. Subodh (1990), and Jadhav and Dhumal (1994) in their genetic study indicated that non-additive gene action was greatly important in controlling the expression of fruit yield and its components in pepper (*Capsicum annuum* L.). In the present study, the mass population of these nine selections exhibited no changes in percentage of fruit set, number of fruits, fruit weight, and fruit yield comparing with the base population 'ALR' indicating that mass selection based on visual screening would not be an efficient method to improve these traits. Two S_1 progenies from the nine plant selections (HD1 and HD12), however, showed higher percentages for fruit set, increased number of fruits, and greater fruit yield than the other tested progenies. These two progenies had also enhanced fruit weight. HD1 and HD12 exhibited the least values for coefficients of variation (CV) indicating better plant homogeneity in these progenies than the other seven. Progeny HD12 had higher percent of fruit set, increased number of fruits, more plant height, and greater fruit yield than progeny HD1. Both progenies were similar in average fruit weight.

The population raised form bulked seeds of S_2 plants screened within HD1 and HD12 progenies (HD1-12) showed higher percentage for fruit set, greater fruit weight, increased number of fruits, and higher fruit yield than the original landrace collection (Table 1). The estimated fruit yield per feddan was 3.3 ton/feddan which was twice the fruit yield produced from the base population. Plants in the improved S_2 population (HD1-12) were more homogeneous in all these traits than the original collection of the land variety. These results suggest that HD1 and HD12 had useful genetic variation for the studied traits under heat and drought stress conditions in this study. Progeny test was helpful to differentiate elite plant genotypes and both HD1 and HD12 seemed to be homozygous in large number of additive-gene loci controlling these traits.

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Table (1): Plant height, percentage of fruit set, fruit weight, fruit number, and fruit yield in an improved population (HD1-12) developed by mass selection from S_2 progenies of two progeny tested plant selections (HD1 and HD12) and the base population of collection in pepper landrace ('ALV') from mid-southern Egypt, 1996.

Entry	Plant height (cm)			Fruit set (%)		
	Range	Mean	CV	Range	Mean	CV
HD1-12	32.0-47	39.4	9.8	33-100	62.5	28.4
Base'ALV'	25.0-57	39.9	23.0	0-75	30.3	61.4
Difference[1]		**0.5 ns**			**32.2 ***	
	Fruit weight (g)			**Number of Fruits**		
	Range	Mean	CV	Range	Mean	CV
HD1-12	08.6-21.2	11.9	24.2	11-28	14.7	23.9
Base'ALV'	00.0-21.1	8.3	56.0	0-28	10.4	55.0
Difference		**3.6 ***			**4.3 ***	
	Fruit yield (g/plant)					
	Range	Mean	CV			
HD1-12	98.4-382.1	175.3	31.8			
Base'ALV'	0.0-491.6	86.3	70.4			
Difference		**89.0 ***				

[1]ns,* Nonsignificant and significant at $P < 0.01$, respectively.

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Morphological and biochemical traits of selected accessions of bird pepper (*Capsicum frutescens* L.)

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Bird pepper (*Capsicum frutescens* L.) is characterized by perennial growth habit and highly pungent fruits with distinctive flavour. The pungent principle capsaicin in chillies has significant physiological action and is widely used by the pharmaceutical industry. Bird pepper has high capsaicin content and is included in British Pharmacopoeia and find maximum use in pharmaceuticals (Tewari, 1988).

MATERIALS AND METHODS

Twenty five bird pepper accessions were evaluated for their morphological and biochemical attributes at College of Horticulture, Kerala Agricultural University, India. The experimental site had a warm humid tropical climate and sandy loam soil with a pH of 5.1. It was located at an altitude of 22.5 m above MSL and between 10°31'N latitude and 76°16'E longitude. The accessions were grown in a randamized block design with two replications. Fifty plants were included per accession in each replications, with a spacing of 60 cm x 45 cm. Characterization of bird pepper accessions was done as per the descriptor list of IBPGR for Capsicum (IBPGR, 1983). The biometric traits observed were plant height, primary branches per plant, days to first flowering and harvest, number of harvests, fruit length, fruit weight, driage and crop duration. Capsaicin content of bird pepper accessions was determined by Folin-Dennis method. Oleoresin in chilli was extracted using solvent acetone. Carotenoids present in fruits of bird pepper was extracted using acetone and its optical density measured at 450 nm. Ascorbic acid content was estimated by 2,6-dichlorophenol indophenol dye method.

RESULTS AND DISCUSSION

Morphological traits

A wide range of variability was observed among bird pepper accessions for morphological traits. The bird pepper accessions were characterized by greenish white corolla, glabrous leaves and persistent fruits. Bird pepper can be distinguished from *C. chinense* by absence of corolla spot and annular constriction at junction of calyx and pedicel. Anther colour was either bluish green, greenish white, cream or cream with slight purple tinge. Fruit position was erect in small fruited types and declining in medium and large fruited types. Fruit shape was either elongate or conical. Fruit colours observed were green, white, light green or yellowish green.

Biometric attributes

The range for plant height; primary branches per plant, plant spread were 41.9 to 75.7 cm, 3.8 to 6.9 and 33.0 to 49.1 cm respectively (Table 1). First harvest of green fruits were obtained in 141 to 167.5 days after planting. Crop duration varied from 173.5 days to 210 days.

Yield attributes

The yield attributes like fruit length, girth, fruit pedicel ratio, fruit weight and yield per plant were recorded. The range for fruit length and girth respectively were 1.66 to 5.08 cm and 1.67 to 3.84 cm. The accession CF 36 registered the maximum fruit length and girth. Wide variation was observed for fruit/pedicel ratio (0.66 to 2.05) and mean fruit weight (0.46 to 1.87 g). There was significant variation among accessions for yield per plant (43.39 to 97.73 g), accession CF 103 recording the highest yield. The other high yielding accessions were CF 10 (92.12 g) and CF 19 (89.81 g). The recovery of dry chilli varied from 20.25 to 25.61 per cent.

Quality attributes

The spice value of bird pepper is determined by content of capsaicin, oleoresin, carotenoids and ascorbic acid. The highest content of ascorbic acid, capsaicin, oleoresin and carotenoids in mature green fruits were registered in accessions CF 15 (77.6 mg 100 g^{-1}), CF 5 (1.57%), CF 23 (14.25%) and CF 138 (0.5%) respectively. The range of ascorbic acid, capsaicin, oleoresin and carotenoids respectively in mature green fruits were 21.0 to 77.6 mg g^{-1}, 0.21 to 1.57 per cent, 14.5 to 14.25 per cent and 0.14 to 0.5 per cent. In general the green fruited accessions of *Capsicum frutescens* had higher capsaicin content compared to white fruited types.

Pruthi (1993) had reported that the capsaicin content of Indian bird chillies is quite high (upto 1.2%) and in African bird chillies and tabasco, it is still higher (1.8%). Most of the accessions evaluated in the present study had high (>1%) or medium high (0.75 to 1%) capsaicin content indicating their enormous economic potential. High pungency chillies are particularly valued for their pungency and are used for manufacture of high capsaicin oleoresin (Govindarajan, 1985).

CONCLUSION

Kerala, lying at the southern end of India is one of the main centres of diversity of *C. fruitescens*. The species characterized by highly pungent fruits has tremendous potential in domestic and international market as it is extensively used by the pharmaceutical industry. Small fruited, highly pungent types in this species is facing damager of extinction and hence its collection, conservation and improvement assumes considerable significance.

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Table 1. Biometric and quality attributes of 25 selected accessions of bird pepper

Sl.No.	Accession No.	Plant height (cm)	Primary branches per plant	Plant spread (cm)	Days to first harvest	Crop duration	Number of harvests	Fruit length (cm)	Pedicel length (cm)
1	CF 5	74.5	6.3	43.5	143.0	187.0	5.6	2.86	2.67
2	CF 10	71.9	5.9	41.5	145.5	191.0	5.7	3.77	3.45
3	CF 11	44.1	4.7	38.1	167.5	208.0	5.3	3.71	2.91
4	CF 15	47.0	5.0	38.5	146.5	196.0	5.3	2.57	1.96
5	CF 18	67.0	5.5	42.3	162.0	205.0	4.9	2.48	2.53
6	CF 19	75.7	5.5	47.8	141.0	173.5	5.6	3.94	2.46
7	CF 23	71.4	6.1	46.0	142.0	194.0	6.0	4.62	3.20
8	CF 27	48.1	4.5	36.5	167.0	210.0	4.6	2.34	2.47
9	CF 28	42.2	3.8	39.4	158.5	195.0	5.4	2.14	2.05
10	CF 34	65.0	4.6	43.3	148.5	189.0	5.3	3.93	2.80
11	CF 36	69.0	5.8	44.1	144.0	190.0	6.0	5.08	3.45
12	CF 37	53.0	4.2	36.6	147.0	196.0	4.7	3.91	1.91
13	CF 53	44.0	4.7	33.0	153.0	208.0	4.7	2.62	2.78
14	CF 66	75.0	5.5	40.2	161.5	205.0	4.7	3.51	2.98
15	CF 77	41.9	4.0	40.3	150.5	193.0	5.2	3.35	2.90
16	CF 84	54.3	4.7	40.3	153.5	206.5	4.8	1.66	2.5
17	CF 103	68.5	6.9	40.3	147.0	193.5	6.3	3.36	2.6
18	CF 135	56.4	6.2	49.1	148.0	196.5	5.6	3.09	2.5
19	CF 136	47.0	4.5	46.0	162.5	205.0	5.1	2.99	2.75
20	CF 138	49.7	5.8	42.2	163.0	208.0	5.0	2.63	2.17
21	CF 139	42.5	3.8	45.1	165.5	210.0	5.0	2.08	2.03
22	CF 146	50.3	5.6	46.1	150.0	202.5	4.8	3.89	2.30
23	CF 147	65.5	6.0	40.3	145.0	192.0	4.8	2.94	1.96
24	CF 153	60.1	5.4	38.9	150.0	204.5	4.9	4.06	3.16
25	CF 156	58.0	6.2	44.5	142.0	198.5	4.5	3.61	1.88
CD (P=0.05)		9.38	1.16	2.18	5.25	6.42	0.52	0.23	0.18

Cont.

Table 1. Continued

Sl. No.	Accession No.	Fruit/ Pedicel ratio	Fruit girth (cm)	Mean fruit weight (g)	Driage (%)	Capsaicin (%)	Oleoresin (%)	Ascorbic acid (mg 100 g^{-1})	Carotenoids (%)
1	CF 5	1.07	2.85	1.07	24.52	1.57	8.25	26.7	0.17
2	CF 10	1.09	3.23	1.12	25.50	1.41	6.25	74.9	0.21
3	CF 11	1.28	2.96	1.22	21.73	0.81	10.25	26.7	0.33
4	CF 15	1.31	2.08	0.85	21.78	1.07	6.25	77.6	0.24
5	CF 18	0.98	2.33	0.74	23.00	0.83	13.75	60.4	0.29
6	CF 19	1.61	3.30	1.53	21.88	0.50	10.00	33.6	0.20
7	CF 23	1.44	3.18	1.34	22.87	0.90	14.25	53.5	0.28
8	CF 27	0.94	1.96	0.64	24.88	0.76	5.00	21.0	0.42
9	CF 28	1.05	2.08	0.46	22.88	1.56	8.75	21.6	0.17
10	CF 34	1.40	2.00	1.32	20.67	0.52	6.25	43.2	0.24
11	CF 36	1.47	3.84	1.87	25.15	0.25	12.5	21.4	0.16
12	CF 37	2.05	2.88	1.20	21.72	0.93	4.75	48.6	0.17
13	CF 53	0.94	2.09	0.54	20.82	0.51	6.75	42.8	0.32
14	CF 66	1.18	3.05	1.28	25.00	0.78	10.05	26.7	0.48
15	CF 77	1.16	2.45	0.95	23.03	1.06	8.75	37.4	0.42
16	CF 84	0.66	1.67	0.49	23.98	0.85	5.50	21.0	0.14
17	CF 103	1.29	2.86	0.95	22.85	0.65	13.75	26.6	0.14
18	CF 135	1.24	2.58	1.27	23.70	0.53	12.75	48.1	0.25
19	CF 136	1.09	3.00	1.07	25.61	0.78	8.5	21.4	0.28
20	CF 138	1.21	2.21	1.86	22.10	0.79	8.00	21.2	0.50
21	CF 139	1.03	2.07	1.47	21.08	0.81	4.5	21.6	0.31
22	CF 146	1.70	2.70	1.25	23.35	0.82	7.75	31.5	0.25
23	CF 147	1.50	2.62	1.07	25.00	1.16	5.00	26.7	0.14
24	CF 153	1.29	3.30	1.39	20.25	0.96	7.75	42.0	0.41
25	CF 156	1.93	2.67	1.28	24.03	0.21	8.15	21.4	0.28
CD (P=0.05)		0.15	0.24	0.07	0.56	10.91	4.51	10.91	0.09

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The identification of genotypes quantitative characters by regressive-cluster analysis

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It's well known that the majority of economically valuable plant characters are polygenic. To identify them in order to select new forms is the main task in today's breeding.

But as before one of the main method which is widely used in quantitative trait determination practice is genetic statistical analysis (or its versions) based on diallel crossing system (1,2). Nevertheless there is a positive experience on molecular marking of some quantitative trait loci (3,4,5,6). But, firstly, the above-mentioned method can be used only for narrow trait spectrum, and, secondly, there are some limitations of this method in regards to low DNA polymorphysm which depends also on the genetic background or cross combination (6). At the same time one of the substantial weakness of the diallel crosses is the impossibility to analyze those genotypes in which nonallel gene interactions are observed, and in case of the nonallel interaction absence the method itself gives only an approximate percentage of allele composition in parental forms and nothing about their identity. Taking this into account, we have tried to carry out the dominant allele structure identification of the investigated sweet pepper genotypes by the number of quantitative traits in case of allelic and nonallel interactions using the regressive-cluster analysis.

Materials and methods

This analysis is based on the schedule of diallel cross [½p(p-1)], of five genotypes of pepper: Prometey, L48, Kolobok, L49, Dobrinya Nikitich (Dobrinya). Crosses were held in cold plastic greenhouse, the central region of Transnistria, in 2002. Plants P_1-P_5 and F_1 were grown according to recommended technology for the culture. Fifty days old seedlings were transplanted in RCBD with two repetitions and 10 plants per repetition in open ground (OG) and cold plastic house (CPH). Hayman's method was employed to estimate genetic parameters, analyses on variance (V_r) and covariance (W_r) followed Fedin's interpretation (1). The regression coefficient and W_r+V_r for each genotype in different conditions were calculated. The final values of W_r+V_r were clustered and the percent of identic alleles was determined in accordance to their expression type (7). Calculations were carried out for the parameters of early maturation and the ability to form somatic embryoids. The length of the vegetation period was subdivided into three phenophases: mass shoots – mass flowering (I), mass flowering – industrial maturity (II), industrial – biological maturity (III). Induction and calculation of somatic embryoid formation was carried out according to the earlier described method (8).

Results and discussions

The results (table 1) shows that the inheritance of the character "length of vegetation period" is complicated and can be differentiated according to the type of combining phenophases. Inheritance type of the I in cold plastic house and the III phenophases in both conditions fits the additive-dominant model (Fig.1). Nonallel interactions take place during the II phenophase and the length of the whole vegetation period. Nonallel gene interactions also were marked for the character "induction" and "total number of formed somatic embryoids" in vitro for both types of explants excided in the phases of torpedo and stick. Thus we can define the genetic variation components of characters only for phenophases I and III (table 2). The analysis of obtained data has shown the dependence of character expression from growing conditions, where dominant alleles not always make for the success of an expression in specific conditions. Expression of characters "length of phenophase I and III" was conditioned by functioning not more than one block of dominant alleles. In general, having described a general inheritance pattern, the diallel analysis did not give a detail characteristic of each genotype on allele composition. To our mind, it may be supplemented with grouping the final W_r+V_r values, showing the relation between character display and the presence of dominant alleles under each particular condition, including variants with nonallel gene interactions, and with processing the obtained array by either variance method, in case of normal distribution, or by Multiple analysis under normal distribution disruption (table 3).

Table 1. - Value of the common regression coefficients of some characters in different conditions and value of W_r-V_r based on diallel crosses.

Character	Cold plastic house					Open ground				
	Common regression coefficient $b_i \pm m$	t_1 difference from 0	t_2 difference from 1	W_r-V_r F	W_r-V_r Significance level	Common regression coefficient $b_i \pm m$	t_1 difference from 0	t_2 difference from 1	W_r-V_r F	W_r-V_r Significance level
1. Phenophase I (I)	0,971 ±0,23	4,214	0,126	1,85* 0,01**	>0,05 >0,05	1,306 ±0,38	3,42	-0,8	5,70 0,04	<0,05 >0,05
2. Phenophase II (II)	0,624 ±0,151	4,14	2,49	9,37 15,22	<0,05 <0,05	0,679 ±0,096	7,08	3,34	1,38 0,46	>0,05 >0,05
3. Phenophase III (III)	1,01 ±0,16	6,148	-0,06	3,68 0,21	>0,05 >0,05	1,05 ±0,170	6,153	0,283	3,47 0,48	>0,05 >0,05
4. The length of whole vegetation period	1,225 ±0,249	4,908	-0,09	5,81 1,65	<0,05 >0,05	0,902 ±0,235	3,83	0,417	5,43 1,45	<0,05 >0,05
In vitro conditions										
	Torpedo phase					Stick phase				
5. Total number of formed embryoids	-0,041 ±0,02	-1,781	45,26	589,97 3,19	<0,05 >0,05	0,098 ±0,043	23,145	0,047	15,82 1,31	<0,05 >0,05

Note: * - values for variants, ** - values for repetition, t_{table}=3.18

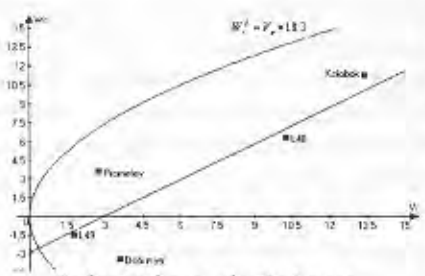
Table 2 - Genetic components of character variations "length of phenophase" in different conditions.

Genetic components	Phase of development			
	mass shoots – flowering		industrial – biological maturity	
	CPH	OG	CPH	OG
$\sqrt{H/D}$	1,211	1,278	0,963	1,039
$r_{(Wr+Vr)y}$	0,94	0,57	-0,93	0,94
h^2/H	0,45	0,41	0,24	0,14
Broad-sense heritability	0,82	0,95	0,92	0,87
Narrow-sense heritability	0,23	0,38	0,42	0,32

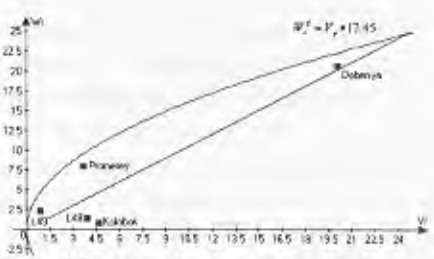
Note: y – phenophases length

Table 3. - Final values W_r+V_r for five genotypes of pepper, character: "the length of phenophase" (data from regression analysis of diallel crosses)

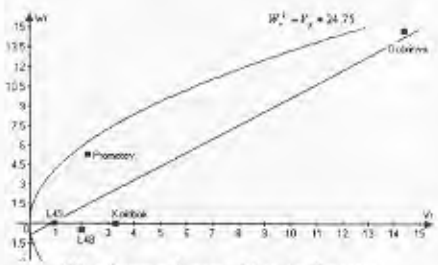
Genotype	Length of I-st phenophase				Length of II-nd phenophase				Length of III-rd phenophase			
	W_r+V_r, cold plastic house		W_r+V_r, open ground		W_r+V_r, cold plastic house		W_r+V_r, open ground		W_r+V_r, cold plastic house		W_r+V_r, open ground	
	N. of case	Values	N. of case	Values	N. of case	Values	N. of case	Values	N. of case	Values	N. of case	Values
Prometey	1	6,35	6	5,125	11	7,85	16	4,75	21	11,63	26	7,58
L48	2	16,575	7	5,775	12	2	17	1,4	22	5,3	27	1,53
Kolobok	3	24,75	8	7,75	13	4,875	18	6,2	23	5,2	28	3,3
L49	4	0,275	9	5,375	14	3,05	19	0,775	24	3,2	29	1,03
Dobrinya	5	0,175	10	-0,85	15	0,825	20	0,725	25	40,8	30	29,1



I phenophase, plastic house



III phenophase, open ground



III phenophase, plastic house

Fig 1. Graph of regression W_r/V_r for character "length of vegetation period in different conditions"

Checking the variety for the correspondence to normal distribution showed its failure. That's why the multitude W_r+V_r was clustered using the program for PC Statistica 5.0. Received tree plot (Fig. 2) of three phenophases in two conditions shows seven cluster groups of five genotypes with different traits expression in frames of each cluster. The discriminant analysis confirmed that fulfilled clusterization was optimal (λ Willks = 0,067; F = 63,926, p<0.0000).

The clusterization was transformed into the scheme for better obviousness (Fig. 3). Expression in different genotypes within the cluster is taken as equal.

The regressive-cluster analysis with certain assumption allows to differ genotypes and phenophases according to the type of expression, as well as to estimate the differential effect of the environment on type of expression. For all this the more different the conditions the more precise identification will be. Under plastic greenhouse conditions 10 expression types are differentiated, and in open ground – 9. Within the differentiating condition two expression type are observed in most genotypes, and only in L48 – three ones. We suppose, that the similar expression type results from the presence of equal dominant alleles. The regressive-cluster analysis allows a purposeful matching of pairs for crosses by the principle of the least identity (Fig. 4).

The range of variability from 0 to 67% points to its significance. The most promising combinations for the plastic greenhouse are: 1x2; 1x4; 2x4; 2x5; 3x4; 3x5; for the open ground– 1x5; 2x5; 3x5. The last two combinations are universal for both environments for this character.

In a similar way the regressive-cluster analysis for the character "number of produced somatic embryoids" was also carried out in explants, isolated at torpedo and stick phase. (Fig. 5). Comparison of dominance degree, estimated earlier for both explant types [8], demonstrates a very good agreement of the data with the carried out clusterization that shows the possibility of determining dominant allele identity by the regressive-cluster analysis. The discriminant analysis also corroborates appropriateness of subdividing into 5 clusters (Wilks λ = 0,0118; F = 139,88, p<0.0000).

The allele identity analysis (Fig. 6) in genotypes by character display at torpedo phase indicates that they are similar in the lines 1 and 4, and also in 3 and 4, but are not identical in these two genotype groups. The lack of agreement in expression identity with the lines 1 and 4 as compared with 3 and 5 at the stick phase shows their quality difference. The data obtained allow assumption of the existence of several types of switch genes from gametophytic to sporophytic pathways, distributed in Capsicum annuum L. gene pool.

Thus, the regressive-cluster analysis allows identification of some quantitative traits in genotypes and intensification of breeding in the necessary direction by optimizing pair matching for crosses.

For promoting the analysis carrying out, the PC program combining all calculation stages is under preparation.

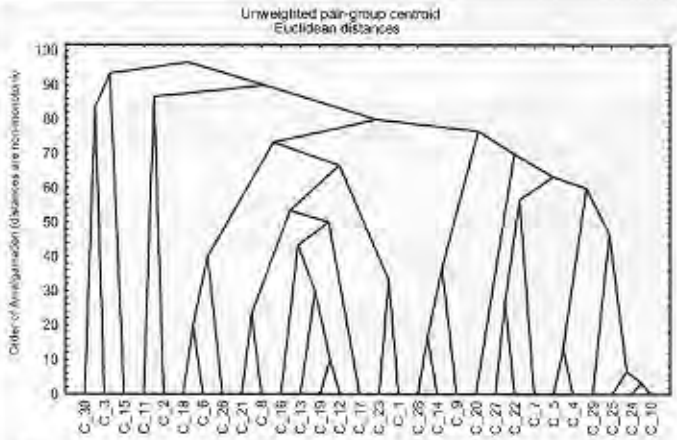


Fig. 2. Expression of the character "length of phenophase", according to value W_r+V_r in different conditions

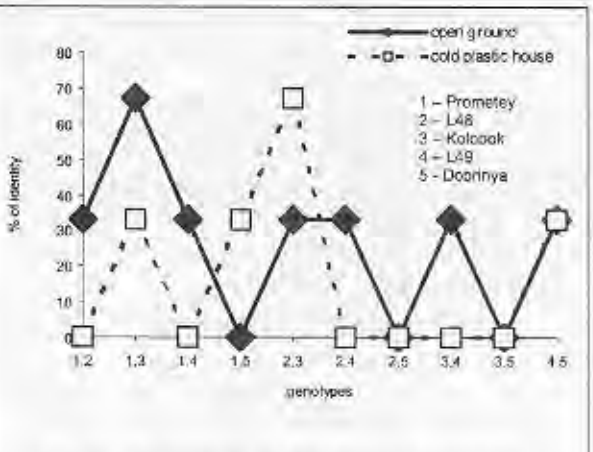


Fig. 4. The identity of five pepper genotypes according to the character expression "length of phenophase" in different conditions.

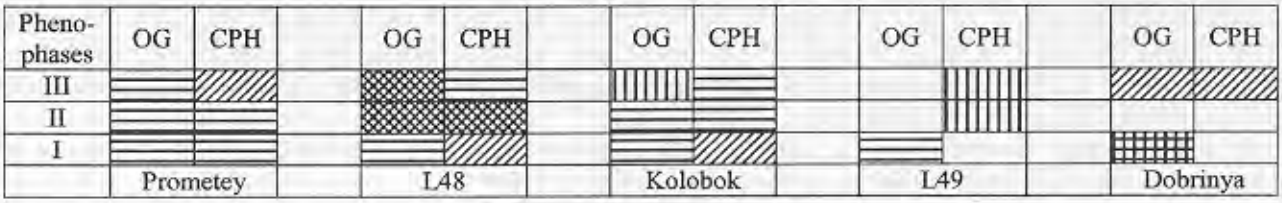


Fig. 3. Expression of character "length of phenophase", according to value W_r+V_r based on the data of cluster analysis.

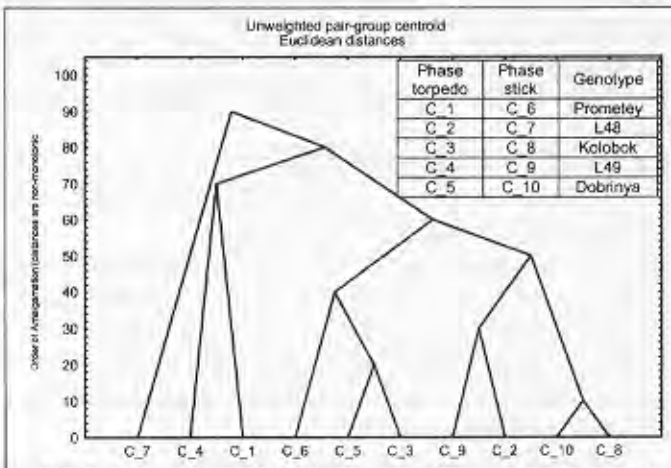


Fig 5. Expression of the character "formation of somatic embryoids", according to value W_r+V_r for explants in the phases of torpedo and stick

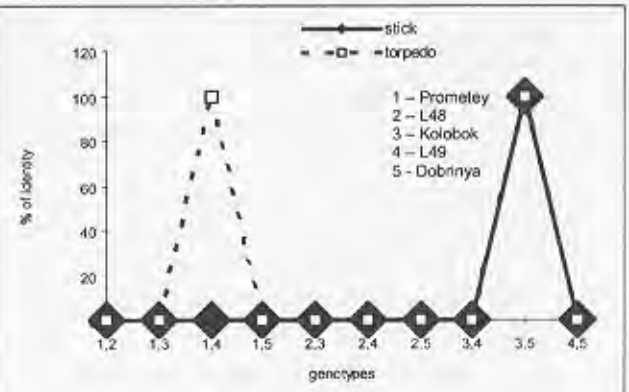


Fig 6. The identity of five pepper genotypes according to expression of the character "formation of somatic embryoids" of explants in the phases of torpedo and stick.

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STUDIES ON GENETIC VARIABILITY IN CAPSICUM (*Capsicum annuum* L.) UNDER MID HILLS OF UTTARANCHAL

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ABSTRACT

This investigation on genetic variability including mean, genotypic and phenotypic variances, coefficients of variation, heritability, genetic advance and genetic gain was conducted with 22 genotypes of capsicum (*Capsicum annuum* L.) under mid hills of Uttaranchal. Significant differences among the genotypes for all the characters were noted. The cultivars Pepper Peprika, Sel. 1-2 and Sel. 1-3 were promising having more than one desirable traits. High phenotypic and genotypic coefficients of variation, heritability and genetic gain were observed for ascorbic acid content, number of fruits per plant, fruit yield per plant, seed yield per fruit and fruit length.

INTRODUCTION

Capsicum (*Capsicum annuum* L.) is considered as one of the most important remunerative crops in pockets of mid hills of Uttaranchal. The fruits are either sold in local markets or supplied to distant places as green vegetable fetching a good return to the farmers. The commercially cultivated variety in Uttaranchal is California Wonder, which is an old introduction. Therefore, identification of superior genotypes among relatively new ones becomes imperative for promoting its production, productivity and the quality of the produce. Considering these points, a study on genetic variability in Capsicum was undertaken.

MATERIAL AND METHODS

The experiment consisting of 22 genotypes of Capsicum was laid out in a randomized block design with three replications during summer-rainy season of 1998. Data were recorded for 18 different traits viz., plant height at 50% flowering (cm), days to 50 % flowering, days to

first picking, leaf area (cm^2), number of branches per plant, fruit length (cm), fruit diameter (cm), pedicel length (cm), pericarp thickness (cm), dry matter content (%), ascorbic acid content (mg/100 g fruit), seed yield per fruit, 1000-seed weight (g), plant height at last picking (cm), number of fruits per plant, number of pickings, fruit weight at edible maturity (g) and fruit yield per plant (g). The data was analyzed statistically as per Gomez and Gomez (1983) and Burton and De vane (1953).

Analysis of variance revealed significant differences among the genotypes for all the traits. Among the genotypes, maximum fruit yield per plant (427.67 g) was recorded in Sel.1-3 followed bySel.1-1 (391.00 g), Sel. 2 (307.00 g) and Sel. 1-2 (305.00 g). These genotypes may be utilized for realizing improved fruit yield per plant. Variability in fruit yield of Capsicum was also shown by Arumugam *and Pa[ppiah* (1989).

The genotype Sel. 1-3 had highest number of fruits per plan (8.73). The genotypes viz., Sel.1-1, Sel.2 and Sel. 1-2 also produced higher number of fruits per plant. This indicated that above four genotypes had greater potential with respect to number of fruits per plant. The yield superiority of these 4 genotypes was largely due to higher number of fruits per plant.

The highest fruit weight at edible maturity was recorded in CW Sel. 1 (66.59 g). For fruit length, Pepper Peprika (15.36 cm) was promising. Maximum fruit diameter was recorded in Neusiedler (6.98cm). Pericarp thickness was found maximum (0.613 cm) in Lieberapfel that indicated greater scope for long distance transportation and long storage period. Early flowering (69 days) was observed in Lieberapfel, Osh Region, Sel. 1-1 and Sel. 1-2. CW-1 andSel.3 were a little later in flowering (71 days). Minimum time taken to first picking was in Sel. 1-2 (101 days) followed by Sel. 1-3 (103 days). Tallest plants at 50 flowering and last picking were observed in Sel 1-2 and Pepper Peprika, respectively. A significant varietal difference was also observed by Adamu and Adu (1989) for various characters.

Ascorbic acid content had a range of 55.10 to 318.13 mg/100g fresh fruit. Highest ascorbic acid content was noted in Sel. 3 followed by Feroz and Sel.2. These genotypes could be utilized as one of parents in crosses to improve ascorbic acid content in Capsicum. Lee *et al.* (1995) reported that Yellow Wax (cv. Hungarian Yellow) exhibited higher ascorbic acid

content in comparison to Jalapeno Peppers (cv. Veracruz), while Serrano peppers (cv. Hidalgo) showed intermediate values.

The genotypes HC 201, Feroz, HC 203, Szegediner and Yolo Wonder registered maximum seed yield per fruit while maximum height of 1000 seeds was recorded in Yolo Wonder (10.92 g). Thus Yolo Wonder can be exploited as promising variety for improved seed production. Variability in seed yield was also observed by Rani and Singh (1996). Dry matter content, days to 50 flowering, leaf area, fruit length and plant height at last picking showed narrow genetic variation.

Based on genotypic and phenotypic variances, pericarp thickness, seed yield per fruit, dry matter content, number of fruits per plant, 1000 seed weight, fruit diameter and fruit length exhibited low variability. For other characters, genotypic and phenotypic variances were high. Low difference between genotypic and phenotypic variances was observed for most of the traits except number of pickings and days to first picking.

The phenotypic coefficient of variation (PCV) values were higher in magnitude than their corresponding genotypic (GCV) values for all the traits. High magnitude of PCV and GCV were recorded for ascorbic acid content, number of fruits per plant and fruit yield per plant, while moderate to high values were recorded for seed yield per fruit. These values indicated scope for improvement of these traits by straight selection.

Moderate PCV and GCV values were observed in fruit length, number of pickings, 1000 seed weight, plant height at 50% flowering, leaf area, pedicel length, pericarp thickness, fruit weight at edible maturity, fruit diameter, plant height at last harvest and number of branches, suggesting these traits had less potential for direct selection. Low GCV for days to 50% flowering, days to first harvest and dry matter content indicated that genotypes possessed comparatively low genetic variation for these traits. High heritability was found for most of the traits under study except pericarp thickness, days to first harvest and number of pickings where moderate heritability was observed.

High heritability for different traits indicated that large proportion of phenotypic variance was due to genotypic variance and therefore, reliable selection could be made for these traits on the basis of phenotype. Earlier findings on habitability by Das et al. (1990); Kumar *et al.* (1993) and Pitchaimuthu and Pappiah (1992) were in agreement with these results.

Johnson et al. (1955) suggested that the estimate of heritability coupled with genetic advance provides better information rather than heritability alone. High heritability along with high GCV and genetic gain was observed for ascorbic acid content, number of fruits per plant, fruit yield per plant, seed yield per fruit and fruit length, indicating that the traits were controlled by additive gene effect (Pause, 1957) and would respond very well to continuous selection.

From the above study on mean performances and other genetic parameters of different plant characters, it was revealed that five characters viz., ascorbic acid content, number of fruits per plant, fruit yield per plant, seed yield per fruit and fruit length were the most important traits for improving the genotypes while plant height at 50% flowering, 1000 seed weight, fruit weight at edible maturity and pericarp thickness were considered as second most important characters for applying selection in capsicum genotypes. Further, four genotypes, viz., Sel. 1-1, Sel. 1-2, Sel. 1-3 and Sel. 2 were found to be superior to California Wonder for number of fruits per plant and fruit yield per plant.

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STUDIES ON GENETIC DIVERGENCE IN CAPSICUM (*Capsicum annuum* L.) IN UTTARANCHAL HILLS

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ABSTRACT

Genetic diversity among 22 Capsicum genotypes was assessed based on 16 yield contributing characters using Mahalanobis D^2 statistic. The genotypes could be grouped into 4 clusters. Cluster I was largest with 16 genotypes followed by cluster II with 3 genotypes, cluster III with 2 genotypes and cluster IV with only one genotype. Cluster IV showed maximum genetic divergence (35.878) with cluster III followed by cluster II (32.670) and cluster I (31.819). Based on genetic divergence ($\sqrt{D^2}$) values, Pepper Peprika x Lieberapfel, Pepper Peprika x Neusiedler, Pepper Peprika x CW-1, Pepper Peprika x CW Sel.1 and Pepper Peprika x Sel.1-2 are suggested as potential crosses to incorporate most of desirable traits in population through hybrid breeding programmes in capsicum under rainfed mid hills of Uttaranchal.

INTRODUCTION

For an efficient breeding programme, selection of genetically divergent parents and superior genotypes is important to procure heterosis and release transgressive segregants. Capsicum (syn. Sweet Pepper, bell pepper, Shimla mirch) is an important vegetable crop of Uttaranchal hills. Farmers generally, grow old introduction like California Wonder. Therefore, identification of divergent superior parents for evolution of potential hybrids to boost the production and quality has become imperative. In chillies, such of works have been done by Sunderum *et al.* (1980); Mehra and Peter (1980), Varaloksh and Haribabu (1991) and Roy and Sharma (1996) but very little work s have been done on capsicum in India.

MATERIALS AND METHODS

Twenty-two genotypes of Capsicum were grown in a randomized block design with three replications under mid hills of Uttaranchal during *Kharif* of 1998. Observations were recorded plant height at 50% flowering (cm),days to 50% flowering, days to first harvest, leaf area (cm^2), number of branches per plant, fruit length (cm), fruit diameter (cm), ascorbic acid content (mg/100 g fruit), seed yield per fruit (g), 1000-seed weight (g), dry matter content (%), pericarp thickness (cm), pedicel length (cm), plant height at last picking (cm), number of fruits per plant, number of pickings, fruit weight at edible maturity (g) and fruit yield per plant (g). Five random plants were tagged for recording data in each treatment. The genetic divergence was estimated using D^2 statistic according to Mahalanobis (1936) and the genotypes were grouped in different clusters following Tocher's method (Rao, 1952).

RESULTS AND DISCUSSION

The analysis of variance revealed significant differences among genotypes for all the characters studied. The D^2 values were calculated corresponding to all possible 231 combinations involving paired combinations among 22 genotypes. The uncorrelated linear combinations of 18 characters differed in their contribution to D^2 estimates. These were used for making clusters (Table 1) and for estimation of inter- and intra-cluster D^2 values and divergence (Table 2). The D^2 values ranged from as small as 8.187 between the genotypes sel.1-1 and RC1-1 to as large as 37.917 between Neusiedler and Pepper Peprika. Twenty-two genotypes used in this investigation were grouped into 4 clusters on the basis of D^2 values. The cluster I was the largest and included 16 genotypes followed by cluster II with 3 genotypes and III with 2 genotypes, while cluster IV had only one genotype. Minimum inter-cluster D^2 value and distance were observed between clusters I and II (25.597 and 5.059, respectively) whereas, the maximum values were recorded between cluster III (Neusiedler, Lieberapfel) and IV (Pepper Paprika) (35.878 and 5.990, respectively). High value of inter-cluster distance indicated more heterogeneous genetic constitution of genotypes included in clusters III and IV. In contrast minimum distance between clusters I and II indicated close relationship among the genotypes included. Minimum intra-cluster D^2 value (22.99) of cluster I indicated much more homogeneity in genetic constitution of genotypes in that cluster while maximum value (29.911) in cluster II expressed high genetic

heterogeneity among genotypes in the same cluster (Varalakshmi and Haribabu, 1991 and Roy and Sharma, 1996).

Cluster IV had highest mean values for number of fruits per plant, dry matter content, fruit length and number of branches whereas, cluster III was promising for fruit diameter and pericarp thickness. Similarly, cluster II exhibited maximum cluster mean for ascorbic acid content, seed yield per fruit, number of pickings and fruit weight at edible maturity (Table 3). Paired crosses among the genotypes of these clusters could be helpful in confluencing the scattered desirable genes (Dangaria et al., 1994; Oliveira et at, 1999). Therefore, crosses viz., Pepper Peprika x Lieberapfel, Pepper Peprika x Neusiedler, Pepper Peprika x CW-1, Pepper Peprika x CW Sel.1 and Pepper Peprika x Sel.1-2 involving highly divergent parents with desirable traits are recommended for future breeding programmes. However, crossing of Pepper Peprika with the genotypes of cluster I should also be considered as the latter had highest mean values for fruit yield per plant, 1000 seed weight and leaf area.

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Table 1: Composition of cluster based on D^2 statistic in capsicum (Capsicum annuum L.)

Sl. No.	Clusters	Number of genotypes	Name of genotypes
1.	I	16	CW Sel.2, Yolo Wonder, SPP, California Wonder, Osh Region, HC-201, HC-203, RC-1, Feroz, Capsicum-13, Szegediner, Sel. 1-1, Sel.1-3, Sel.2, SeL3 and RC1-1.
2.	II	3	CW-1.CWSel.I, Sel.1-2
3.	III	2	Neusiedler, Lieberapfel
4.	IV	1	Pepper Paprika

Table 2: Average Inter- and intra-cluster D^2 values (Light) and distance (Dark)

Clusters	I	II	III	IV
I	22.991 **4.795**	25.597 **5.059**	27.811 **5.274**	31.819 **4.583**
II		23.553 **5.641**	29.911 **5.469**	32.670 **5.716**
III			28.273 **5.317**	35.878 **5.990**
IV				-

Table 3.Cluster mean for plant growth and fruit yield characters in Capsicum annuum L.

Sl. No.	Characters	Cluster mean			
		I	II	III	IV
1.	Plant height at 50% flowering (cm)	8.07	10.87	7.10	12.43
2.	Days to 50% flowering	74.13	72.00	74.50	78.00
3.	Days to first harvest	111.15	108.67	108.50	120.33
4.	Leaf area (cm^2)	38.96	35.19	37.19	33.17
5.	Number of branches per plant	8.75	8.26	7.60	9.80
6.	Fruit length (cm)	6.80	7.29	5.36	15.36
7.	Fruit diameter (cm)	5.21	5.37	6.37	2.21
8.	Ascorbic acid content (mg/100 g fruit)	4.13	4.09	3.05	6.21
9.	Seed yield per fruit (g)	0.412	0.379	0.543	0.293
10.	1000 seed weight (g),	5.64	6.33	5.57	7.17
11.	Dry matter content (%)	152.82	160.85	143.22	80.93
12.	Pericarp thickness (cm)	6.50	6.69	4.46	5.87
13.	Pedicel length (cm)	1.58	1.35	0.945	0.965
14.	Plant height at last picking (cm)	37.63	38.24	36.19	57.93
15.	Number of fruits per plant	4.93	3.49	2.83	6.13
16.	Number of pickings	4.40	4.78	2.84	2.33
17.	Fruit weight at edible maturity (g)	52.52	55.67	47.00	31.92
18.	Fruit yield per plant (g).	253.54	181.22	145.17	195.33

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VARIABILITY, HERITABILITY AND GENETIC ADVANCE IN WAX TYPE CHILLI (*CAPSICUM ANNUUM* L.)

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INTRODUCTION

Chilli (*Capsicum annuum* L.) is one of the most versatile crops, grown as avegetable as well as spice crop. Indigenous to Central and South America and the West Indies, it has been cultivated for hundreds of years throughout the world. It is grown throughout India, and our country tops the world in area and production. Chilli is grown in an area of 9.56 lakh ha with an annual production of 9.45 lakh tonnes and a productivity of 0.9 t ha^{-1}. Wax type chilli is a distinct horticultural group with light yellow, shining waxy fruits that are mainly used for salad purposes and in the preparation of snacks. Suited for pot cultivation also, they are the most premium types fetching maximum price in the market. Most wax type chillies cultivated in India are introductions from different countries. Natural crossing of these with indigenous types have resulted in considerable variability among them. Considering their importance, the present study was undertaken to estimate the genetic variability, heritability and genetic advance in a germplasm collection of wax type chillies.

MATERIALS AND METHODS

The experiment was carried out at the College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, India, during 2002-2003. The experimental material consisted of 25 genotypes of wax type chilli collected from various agroclimatic regions of South India. The experiment was conducted in Randomised Block Design with 3 replications. Ten plants were maintained in each plot. All the recommended cultural operations were carried out as per the package of practices recommendations of Kerala Agricultural University (KAU, 2002). Biometric observations were recorded from 5 plants selected at random in each genotype, according to 'Descriptors for *Capsicum* spp' by IPGRI. Observations were recorded on plant height, number of primary branches, number of secondary branches, plant spread, days to first flowering, fruit length, fruit width, number of fruits per plant, green fruit yield per plant, average fruit weight, number of seeds per fruit, 100-seed weight, fruiting span and crop duration. Analysis of variance and covariance for various characters was done. Heritability and genetic advance (at 5% intensity of selection) also were calculated.

RESULTS AND DISCUSSION

Analysis of variance revealed that the genotypes showed significant difference for all the traits studied. Higher values of GCV and PCV were obtained (Table 1) for green fruit yield per plant, number of fruits per plant and average fruit weight, indicating more scope for their improvement through selection. Number of days to first flowering had the lowest value for PCV and GCV. High values of GCV have been obtained earlier for fruit weight and for number of fruits (Arya and Saini, 1977; Vijayalakshmi *et al.* 1989; Nandi, 1993 and Munshi and Behera, 2000).

A high value of heritabiltiy was observed for most of the characters. Heritability was highest for fruiting span followed by crop duration, number of days to first flowering, 100-seed weight, fruit length, average fruit weight, number of fruits per plant and green fruit yield per plant. This was in accordance with the reports of Singh *et al.* (1981), Das *et al.* (1990), Das and Choudhary (1999) and Gogoi and Gautam (2002).

Green fruit yield per plant recorded the highest genetic advance followed by average fruit weight, number of fruits per plant, 100-seed weight and fruit length. High genetic advance was also reported for yield by Choudhary *et al* (1985) and for number of fruits per plant by Elangovan *et al* (1981.

Heritability estimates along with genetic advance is more useful than using heritability value alone in predicting the resultant effect of selecting the best individuals. High heritability along with high genetic advance was observed for 100-seed weight, fruit length, average fruit weight, number of fruits per plant, green fruit yield per plant, fruiting span and number of secondary branches. High heritability combined with high genetic advance could be treated as an indication of additive gene action and selection based on these characters would be ideal. Meshram (1987), Sahoo *et al.* (1989), Das *et al.* (1989), Jabeen *et al.* (1999), Munshi and Bahera (2000), Ibrahim *et al.* (2001) and Sreelathakumary and Rajamony (2002) also reported that fruit yield showed high heritability coupled with genetic advance, along with many other characters.

Thus the present study revealed that characters viz. number of fruits per plant, green fruit yield per plant and average fruit weight should be given more importance in selection programmes for the improvement of wax type chilli.

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Table 1. Genetic parameters with respect to various characters in wax type chilli

Characters	Variance			Coefficient of variation			Heritability %	Genetic advance (as % of mean)
	σ^2p	σ^2g	σ^2e	PCV	GCV	ECV		
Plant height	17.681	4.304	13.377	9.97	4.92	5.05	24.34	5.00
Number pf primary branches	0.662	0.260	0.402	14.08	8.83	5.25	39.33	11.24
Number of secondary branches	7.888	5.228	2.660	17.65	14.37	3.28	66.28	24.07
Plant spread	5.910	3.669	2.241	7.41	5.84	1.57	62.08	9.48
Number of days to first flowering	11.033	9.683	1.350	4.90	4.59	0.31	87.76	8.85
Fruit length	2.692	2.348	0.344	26.41	24.67	1.74	87.22	47.5
Fruit width	0.433	0.293	0.140	10.79	8.88	1.91	67.75	15.08
Number of fruits per plant	93.187	69.726	23.461	34.58	29.92	4.66	74.82	53.31
Green fruit yield / plant	5031.653	3741.137	1290.516	42.31	36.48	5.83	74.35	64.8
Average fruit weight	6.674	5.679	0.995	33.77	31.15	2.62	85.10	59.22
Number of seeds per fruit	111.003	24.947	86.056	26.68	13.11	13.57	22.40	12.81
100 seed weight	0.006	0.006	0	29.53	27.65	1.88	87.64	52.03
Fruiting span	70.122	65.170	4.952	13.08	12.61	0.47	92.94	25.04
Duration of the crop	71.889	64.556	7.333	6.42	6.09	0.33	89.80	11.88

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CORRELATION AND PATH COEFFICIENT ANALYSIS FOR YIELD IN HOT CHILLI (*CAPSICUM CHINENSE* JACQ.)

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INTRODUCTION

In hot chilli (*Capsicum chinense* Jacq.), a wide range of variability is available due to its cross pollinated nature. This variability will be helpful in the improvement of this crop. In any crop improvement programme it is prerequisite to critically assess the interrelationship for yield and its contributing characters. Correlation studies provide information about the nature and magnitude of various associations among the traits. Path coefficient analysis assesses the direct and indirect associations and reveals the most reliable yield contributing characters. Keeping in view the above facts, the present investigation was conducted to determine the nature and degree of association among the characters and their direct and indirect effects on yield in *C. chinense*.

MATERIALS AND METHODS

Fifteen accessions of hot chilli (*Capsicum chinense*) collected from different parts of Kerala were evaluated at the College of Agriculture, Thiruvananthapuram, Kerala, India during 1998 – '99. The experiment was conducted in randomised block design with two replications. Ten plants were maintained per plot. Five plants were selected randomly from each accession and observations were recorded on plant height, stem girth, leaf area, days to first flower, fruits per plant, fruit length, fruit girth, fruit weight and yield per plant. Correlation of various biometrical characters was undertaken as per the procedure suggested by Singh and Choudhary (1979). Path coefficient analysis using genotypic correlation coefficient was carried out according to Dewey and Lu (1959).

RESULT AND DISCUSSION

In majority of the characters, genotypic correlation coefficient was found to be higher in magnitude than phenotypic correlation coefficient indicating a strong inherent association among various characters (Table 1). Similar observations were made in chilli by Sundaram and Ranganathan (1978), Rao and Chonkar (1981) and Choudhary *et al.* (1985). The phenotypic and genotypic correlation coefficient revealed that the association of plant height with other traits was low. Days to first flower was found to be negatively correlated with fruits per plant, fruit length and yield. The results are in conformity with the findings of Ahmed *et al.* (1997). Yield per plant showed highly significant positive correlation with fruits per plant, fruit length, fruit girth and fruit weight suggesting that these characters are the most

important yield components and that effective improvement in yield can be achieved through selection based on these characters. Fruit length and fruit girth showed significant positive correlation with fruit weight. Significant positive association of economic traits like fruits per plant, fruit length, fruit girth and fruit weight with yield was also reported earlier in *C. frutescens* by Sheela (1998) and Sreelathakumary and Rajamony (2003).

The results of path analysis revealed that fruits per plant, fruit weight, fruit girth and plant height had shown positive direct effect on yield while stem girth, leaf area, days to first flower and fruit length had exerted negative direct effect on yield (Table 2). The direct effect of fruits per plant was positive and much higher than its genotypic correlation with yield. Positive direct effect of number of fruits was supported by Gill *et al.*, (1977), Sundaram and Ranganathan (1978) and Munshi *et al.*, (2000) in chilli. Though the direct effect of fruit length was negative, its indirect effect through fruits per plant, fruit girth and fruit weight was high and positive indicating that indirect selection for fruits per plant, fruit girth and fruit weight can increase yield. Fruit girth and fruit weight recorded positive direct effect towards yield and their indirect effect through each other were also positive. Rao and Chonkar (1981) also reported positive direct effect of fruit weight on yield in chilli.

The direct effect of plant height was positive. It exerted high and positive indirect effect through fruits per plant and fruit length. The low residual effect (0.0076) indicated that all the important characters are correlated with yield. Rao and Chonkar (1981) and Munshi *et al.*, (2000) also observed low residual value on their study. Based on correlation and path analysis studies, it could be concluded that selection for fruits per plant, fruit weight, fruit length and fruit girth might lead to increase in the yield of *C. chinense.*

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Table 1. Genotypic and phenotypic correlation co-efficient among the characters in *Capsicum chinense*

Character		Stem girth	Leaf area	Days to first flower	Fruits/ plant	Fruit length	Fruit girth	Fruit weight	Yield / plant
Plant height	P	-0.1727	0.4126*	-0.0969	0.3945	-0.2088	-0.2673	-0.1942	0.1735
	G	-0.1977	0.5496**	-0.0902	0.4108*	-0.2285	-0.3036	-0.2870	0.1866
Stem girth	P		-0.2124	-0.3441	0.0697	0.4418*	0.4742**	0.4178**	0.3477
	G		-0.2141	-0.3953	0.0826	0.4545**	0.4967**	0.4426**	0.3713**
Leaf area	P			-0.1755	0.1949	-0.1441	-0.1636	-0.0075	0.1290
	G			0.0097	0.2606	-0.1495	-0.2031	0.1043	0.1603
Days to first flower	P				-0.6311	-0.5733**	0.1166	0.0703	-0.4536**
	G				-0.8575**	-0.7053**	0.1537	0.0156	-0.5855**
Fruits/ plant	P					0.3886*	-0.2437	-0.3051	0.4842**
	G					0.4130*	-0.2509	-0.3875*	0.4687**
Fruit length	P						0.5043**	0.3841*	0.6338**
	G						0.5065**	0.3970*	0.6441**
Fruit girth	P							0.8243**	0.5422**
	G							0.8669**	0.5584**
Fruit weight	P								0.5783**
	G								0.5950**

*, ** Significant at 5 % and 1 % level respectively. P – Phenotypic correlation coefficient G – Genotypic correlation coefficient.

Table 2. Direct and indirect effect of characters on yield per plant in *C. chinense*

Character	Plant height	Stem girth	Leaf area	Days to first flower	Fruits/ plant	Fruit length	Fruit girth	Fruit weight	Genotypic correlation coefficient
Plant height	**0.0515**	-0.0737	-0.0166	0.0037	0.4677	0.0703	-0.1313	-0.2519	0.1866
Stem girth	-0.0102	**-0.3727**	0.0065	0.0162	0.0940	-0.1399	0.2147	0.3884	0.3713
Leaf area	0.0283	-0.0798	**-0.0302**	-0.0004	0.2967	0.0460	-0.0878	0.0915	0.1603
Days to first flower	-0.0046	-0.1473	-0.0003	**-0.0409**	-0.9762	0.2171	0.0664	0.0137	-0.5855
Fruits/ plant	0.0211	0.0308	-0.0079	0.0351	**1.1385**	-0.1271	-0.1085	-0.3401	0.4687
Fruit length	-0.0118	0.1694	0.0045	0.0289	0.4702	**-0.3078**	0.2190	0.3484	0.6441
Fruit girth	-0.0156	0.1851	0.0061	-0.0063	-0.2856	-0.1559	**0.4323**	0.7608	0.5584
Fruit weight	-0.0148	0.1649	-0.0031	-0.0006	-0.4412	-0.1222	0.3748	**0.8776**	0.5950

(Residual, R = 0.0076). Figures in bold are the direct effects.

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CORRELATION AND PATH COEFFICIENT ANALYSIS IN FIVE SPECIES OF *CAPSICUM*

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Introduction

Presence of high level of genetic diversity makes selection an efficient method of improvement in genus *Capsicum*. Thorough understanding of character association is a pre-selection necessity, which facilitates the improvement of the character of interest, very often yield, by selection for any character with significant positive correlation. Correlation between any two characters is a sum of direct as well as indirect effect of one character on another through other characters under consideration and path coefficient analysis helps to split correlation into these direct and indirect effects. For this reason, the present study was conducted to elucidate the nature and quantum of association among quantitative characters and their direct as well as indirect effects on dry fruit yield.

Material and Methods

In the present study, weightage was given to the general association of quantitative characters in *Capsicum* since many of the previous workers in this line were species specific and therefore hot pepper, bell peppers and wild species were simultaneously used. Fifty six accessions which were previously obtained from different parts of the world, comprising of 48 hot peppers (*C. annuum*) of which 4 male sterile, 2 bell peppers (*C. annuum* var. *grossum*), one each of *C. chinense*, *C. frutescens* and *C. praetermissum*, 2 *C. baccatum* ssp. *baccatum* and 1 *C. baccatum* ssp. *baccatum* x *C. baccatum* spp. *pendulum* were raised in randomized block design with 3 replications in vegetable breeding block at IIHR during rabi of 2001-02 and again in kharif 2002. Observations on 16 quantitative characters were recorded following the IPGRI descriptors. Correlation between these characters were worked out by following the procedures detailed by Al-Jibouri *et al.* (1958) and path coefficients by following Dewey and Lu (1959).

Results and Discussion

High level of genotypic influence and lesser environmental effect on character expression was evident from the higher values of genotypic correlation coefficients compared to phenotypic coefficients. At 5% level, yield was positively and significantly correlated with fruit width, fruit length, single fruit weight, seed number, 1000 seed weight and flower weight and at 1% level, positive significant correlation was observed with fruit number and fruit wall thickness (Table 1). This shows that a selection based on fruit characteristics and especially on number and wall thickness can result in lines with higher yield potentials. This positive association of fruit number and fruit yield was previously reported by Gopalakrishnan *et al.* (1985), Choudhary and Das (1998) and Nandadevi and Hosamani (2003). Positive correlation of fruit wall thickness that is yet to be reported might have been highlighted due to the inclusion of bell peppers in the study. The negative correlation between fresh fruit yield and recovery ratio is not a desirable character especially since the hot peppers are used in dry form for export as well as domestic purposes. But the negative correlation of fresh fruit yield and days taken for 50 per cent flowering is highly desirable since earliness and higher yield could be coupled in selected lines. This result is parallel with the observations of Lakshmaiah and Murthy (1984) and Warade *et al.* (1996).

Positive correlation of fruit number with plant height and canopy width and negative correlation of the same with seed number, single fruit weight and fruit wall thickness and positive correlation of fresh fruit yield with seed number and thousand seed weight got direct applications in selection procedures and these are in agreement with the results given by Usharani (1996). Recovery ratio was negatively correlated with fruit width, length, wall thickness and weight. Fruit width was positively correlated with wall thickness and seed number and negatively with days taken for 50% flower opening. Also, single fruit weight had positive correlation with seed number and days taken for 50% flower opening and seed number had negative correlation with days taken for 50% flower opening.

Path analysis has revealed the high direct positive effect of recovery ratio on dry fruit yield (Table 2). Recovery ratio also had a positive indirect effect through flower weight. This suggests that direct selection for fresh fruit yield as well as recovery ratio and indirect selection through flower weight will lead to higher dry fruit yield. Fruit width and fruit length also had direct positive effect and their indirect effect through fresh fruit yield and fruit number were complementary for dry fruit yield. These observations are in confirmity with the results of Basavaraj (1997). Fruit number had a direct positive effect on dry fruit yield and its indirect positive effect through fresh fruit yield, recovery ratio, fruit wall thickness, single fruit weight and seed number had resulted in a high level positive correlation between these characters. Direct positive effect of fruit number on yield was previously given by Sreelathakumary and Rajamony (2003) and Kumar *et al.* (2003). Thousand seed weight, plant height and canopy width also had direct positive effect on dry fruit yield.

The results of the above discussion points to a selection based on fruit and seed characteristics in *Capsicum*. Fruit number, length and width got profound direct influence on fruit yield and selection for plant height and canopy width also lead to higher yields. In case of hot peppers, recovery ratio and thousand seed weight should also be included in selection criteria.

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Table 1: Genotypic (upper diagonal) and phenotypic (lower diagonal) correlation between 16 morphological characters in *Capsicum spp.*

	Fruit number	Fresh fruit yield	Recovery ratio	Fruit length	Fruit width	Fruit pedicel length	Fruit wall thickness	Number of locules	Single fruit weight	Seed number	1000 seed weight	Plant height	Canopy width	Days for 50% flower opening	Dry yield	Flower weight
Fruit number	1	0.470**	0.399**	-0.207	0.391**	0.049	-0.341**	0.368**	-0.406**	-0.307*	0.117	0.368**	0.440**	-0.008	0.714**	-0.406**
Fresh fruit yield	0.404**	1	-0.349**	0.260*	0.272*	0.092	0.344**	-0.056	0.288*	0.296*	0.288*	-0.043	0.135	-0.409**	0.885**	0.315*
Recovery ratio	0.364**	-0.336**	1	-0.321*	-0.604**	-0.074	-0.709**	-0.445**	-0.620**	0.442**	0.160	0.243	0.274*	0.321*	0.107	-0.667**
Fruit length	-0.186	0.233	-0.301*	1	-0.020	0.369**	0.036	0.014	0.190	0.145	0.348**	0.092	0.193	-0.249	0.165	0.150
Fruit width	0.345**	0.258*	-0.595**	-0.023	1	-0.154	0.908**	0.473**	0.959**	0.761**	0.060	-0.352**	-0.307*	-0.291*	-0.073	0.813**
Fruit pedicel length	0.041	0.003	-0.052	0.320*	-0.148	1	-0.069	-0.129	-0.079	-0.235	0.034	0.334**	0.309*	0.223	0.070	-0.028
Fruit wall thickness	-0.310*	0.322*	-0.694**	0.037	0.875**	-0.052	1	0.536**	0.888**	0.605**	0.006	-0.163	-0.153	-0.395**	-0.040	0.844**
Number of locules	0.238	-0.063	-0.321*	0.025	0.310*	-0.063	0.387**	1	0.460**	0.286*	-0.194	-0.028	-0.060	-0.064	-0.256*	0.555**
Single fruit weight	-0.369**	0.273*	-0.611**	0.179	0.925**	-0.059	0.875**	0.352**	1	0.776**	0.142	-0.293*	0.234	0.282*	-0.061	0.825**
Seed number	-0.270*	0.269*	0.418**	0.128	0.719**	-0.206	0.569**	0.193	0.741**	1	0.149	-0.365**	-0.347**	-0.260*	0.064	0.528**
1000 seed weight	0.089	0.273*	0.157	0.323*	0.06	0.025	0.003	-0.138	0.137	0.137	1	0.057	0.206	-0.195	0.395**	0.094
Plant height	0.308*	-0.033	0.234	0.09	-0.331**	0.266*	-0.155	-0.006	-0.279*	-0.331**	0.056	1	0.712**	-0.036	0.125	-0.202
Canopy width	0.393**	0.123	0.245	0.168	-0.281*	0.244	-0.14	-0.004	0.213	-0.321*	0.185	0.664	1	-0.220	0.302*	0.118
Days for 50% flower opening	-0.001	-0.388**	0.315*	-0.237	-0.279*	0.194	-0.386**	-0.05	0.280*	-0.244	-0.192	-0.035	-0.197	1	-0.269*	-0.384**
Dry yield	0.641**	0.848**	0.106	0.158	-0.073	0.069	-0.04	-181	-0.06	0.057	0.392*	0.12	0.281*	-0.265*	1	0.069
Flower weight	-0.368**	0.302*	-0.658**	0.139	0.793**	-0.022	0.815**	0.411**	0.811**	0.499**	0.092	-0.195	0.109	-0.376**	0.069	1

Table 2 : Genotypic path analysis for dry fruit yield per plant (Matrix of direct and indirect effects)

	Fresh fruit yield	Recovery ratio	Fruit length	Fruit width	Fruit pedicel length	Fruit wall thickness	Number of locules	Single fruit weight	Seed number	1000 seed weight	Plant height	Canopy width	Days for 50% flower opening	Flower weight	Fruit number	Correlation coefficient with dry yield
Fresh fruit yield	**1.114**	-0.131	0.014	0.057	-0.004	-0.045	-0.005	-0.033	-0.005	0.001	-0.003	0.001	-0.001	-0.056	-0.019	0.885**
Recovery ratio	-0.389	**0.376**	-0.017	-0.126	0.003	0.093	-0.038	0.072	0.008	0.000	0.018	0.002	0.001	0.119	0.016	0.107
Fruit length	0.289	-0.121	**0.053**	-0.004	-0.014	-0.005	0.001	-0.022	-0.003	0.001	0.007	0.002	0.000	-0.027	0.008	0.165
Fruit width	0.303	-0.227	-0.001	**0.209**	0.006	-0.120	0.041	-0.112	-0.013	0.000	-0.027	-0.003	0.000	-0.145	0.016	-0.073
Fruit pedicel length	0.103	-0.028	0.019	-0.032	**-0.038**	0.009	-0.011	0.009	0.004	0.000	0.025	0.003	0.000	0.005	0.002	0.070
Fruit wall thickness	0.383	-0.267	0.002	0.190	0.003	**-0.132**	0.046	-0.103	-0.010	0.000	-0.012	-0.001	-0.001	-0.151	0.014	-0.040
Number of locules	-0.062	-0.167	0.001	0.099	0.005	-0.071	**0.086**	-0.053	-0.005	0.000	-0.002	-0.001	0.000	-0.099	0.015	-0.256*
Single fruit weight	0.321	-0.233	0.010	0.201	0.003	-0.117	0.039	**-0.116**	-0.013	0.000	-0.022	-0.002	0.000	-0.147	0.016	-0.061
Seed number	0.330	-0.166	0.008	0.159	0.009	-0.080	0.024	-0.090	**-0.017**	0.000	-0.028	-0.003	0.000	-0.094	0.012	0.064
1000 seed weight	0.321	0.060	0.018	0.013	-0.001	-0.001	-0.017	-0.016	-0.003	**0.002**	0.004	0.002	0.000	0.017	-0.005	0.395**
Plant height	-0.048	0.091	0.005	-0.074	-0.013	0.022	-0.002	0.034	0.006	0.000	**0.076**	0.006	0.000	0.036	-0.015	0.125
Canopy width	0.150	0.103	0.010	0.064	0.012	0.020	0.005	0.027	0.006	0.000	0.054	**0.009**	0.000	0.021	-0.018	0.302*
Days to 50% flower opening	-0.456	0.121	0.013	0.061	0.009	0.052	0.005	0.033	0.004	0.000	-0.003	-0.002	**0.002**	0.069	0.000	-0.269*
Flower weight	0.352	-0.251	0.008	0.170	0.001	0.111	0.048	-0.096	-0.009	0.000	-0.015	-0.001	-0.001	**-0.179**	0.016	0.069
Fruit number	0.524	0.150	-0.011	-0.082	0.002	0.045	-0.032	0.047	0.005	0.000	0.028	0.004	0.000	0.072	**0.040**	0.714**

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COMBINING ABILITY STUDIES IN INDIAN AND EXOTIC GERMPLASM OF CAPSICUM (*Capsicum annuum* L.)

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ABSTRACT

Seven capsicum genotypes and their hybrids in all possible combinations were tested for GCA and SCA. Results indicated that genotypes CW (T), Yolo Wonder, SPP and RC-1 appeared as promising general combiners for fruit diameter, fruit weight, number of seeds per fruit and fruit yield per plant Genotypes HC-201, Paprika and RC-1 were best combiners for number of fruits per plant. The crosses CW (T) x SPP, CW (N) x RC-1, HC-201 x SPP, HC-201 x RC-1,Yolo Wonder x RC-1, Paprika x CW (N) and HC-201 x CW (N) had SCA effects. Therefore, these were important crosses to incorporate desirable traits in vigourous hybrids in capsicum.

INTRODUCTION

Capsicum was introduced in India as a quite new vegetable. Some old introductions were in cultivation even today in different regions of country with mild temperature condition but increasing demand of the produce in urban people has necessitated to boost up the production of the crop. Very little progress has been made in improvement of this crop. Some promising hybrids developed by private sectors are insufficient to meet the demand for produce. Therefore, identifying suitable parents with good combining ability for important fruit yield and quality attributes to develop F1 hybrids suited to different agro-climates is an avenue of immense importance. Keeping the facts in view this investigation was undertaken in mid hills of Uttaranchal.

MATERIALS AND METHODS

Seven genotypes of Capsicum *(Capsicum annuum L.)* of divergent origin were grown in row to row and plant to plant distances of 45cm and 30 cm, respectively. Recommended cultural practices were adopted to raise the crops during (1999-2000). These genotypes were mated with each other in all possible combinations in half diallel pattern resulting in twenty-one F1 progenies. The crops of the parents along with progenies were raised in succeeding year (2000-2001) in randomized block design with three replications adopting recommended cultural operations for the region. Data recorded for days to first harvest, leaves per plant, leaf area (cm), fruit length (cm), fruit diameter (cm), fruit weight (g), flesh thickness (cm), number of fruits per plant, number of pickings, number of seeds per fruit, fruit yield per plant (g), ascorbic acid content (mg/100 g fruit) and total soluble solids (%) were analyzed statistically to partition the variance in to different sources to estimate the general and specific combining ability components in accordance with Griffing (1956).

RESULTS AND DISCUSSION

Analysis of variance indicated that the general combining ability variances were significant for the all the characters among crosses. General combining ability effects of 7 parental lines (Table 1) indicated that HC-201 and CW (N) were best combiner for leaves per plant. Highly significant positive GCA effects were recorded for genotypes SPP and Paprika for fruit length. Genotypes CW (T), Yolo Wonder, SPP and RC-1 appeared as promising general combiners for fruit diameter, fruit weight, number of seeds per fruit and fruit yield per plant where as significant positive GCA effects were observed by RC-1, YW, CW (N), CW (T), and HC-201for ascorbic acid content and Yolo Wonder for total soluble solids. Genotypes HC-201, Paprika and RC-1 were best combiners for number of fruits per plant where as RC-1 and Paprika could be used to develop good $F1^s$ for more number of pickings suited to "Kitchen Gardens."

For many of the characters, the parents RC-1, SPP, YW, CW (T) and Paprika were found good combiners. Therefore, these lines can be used in hybridization for producing promising

combinants. High GCA effects for some characters in Capsicum have been reported by Gill and Thakur (1973), Sharma and Saini (1977), Chen (1985), Dikki and Studentsova (1986), Kaul and Sharma (1988), Oliveira (1988), Ravindra et al. (1977), Vallejo et al. (1977) and Zecevic et al. (1977).

The SCA effects for hybrids pertaining to different characters are given in Table1, SCA, which represents the predominance of non-additive gene action, is a major component that may be utilized in heterosis breeding. The crosses CW (T) x SPP, CW (T) x RC-1, Yolo Wonder x SPP, Yolo Wonder x RC-1 and SPP x RC-1 were good specific combiners for early bearing. The best SCA effects for leaves per plant was exhibited by combination CW x SPP and CW (N) x RC-1 were promising for leaf area and plant height, respectively. Specific combiners HC201 x SPP and HC-201 x RC-1 imposed highest effect for fruit length and fruit diameter, respectively.

The crosses CW (N) x RC-1 and CW (T) x Yolo Wonder were good specific combinations for fruit weight. Cross combinations Yolo Wonder x RC-1, CW (T) x RC-1and Paprika x SPP had high SCA effects on number of fruits per plant whereas, specific combinations CW (N) x RC-1 was promising for number of number of pickings.

Crosses involving Paprika x CW (N) and CW (N) x Yolo Wonder had maximum SCA effects for number of seeds per fruit. High values of SCA effect for fruit yield per plant was obtained in crosses Yolo Wonder x SPP, CW (N) x RC-1, CW (T) x RC-1, CW (T) x Yolo Wonder, CW (N) x SPP, Yolo Wonder x RC-1 and HC-201 x RC-1. Maximum SCA effects for quality determining character of fruit e.g., ascorbic acid content was exhibited by combination Paprika x CW (N) followed by HC-201 x Yolo Wonder, HC-201 x CW (N), HC-201 x CW (T) and HC201 x SSP whereas, cross combination HC-201 x CW (N) was highly specific for total soluble solids of fruit.

Above observations indicated that high general combining ability of parents seems to be reliable criterion for the prediction of specific combining ability. Heterosis in the crosses involving low and high combiners might be due to dominant x additive type of interaction which is partially fixable and the crosses involving both the poor combining parents showing high SCA must be due to intra- and inter-allelic interactions.

From the above studies, it is concluded that the crosses CW (T) x SPP, CW (N) x RC-1, HC-201 x SPP, HC-201 x RC-1,Yolo Wonder x RC-1, Paprika x CW (N) and HC-201 x CW (N) were important to incorporate desirable traits in vigourous hybrids in capsicum.

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Table 1: General combining ability (GCA) of different parents in capsicum (*Capsicum annuum* **L.**)

Type	Days to first harvest	Leaves per plant	Leaf area	Plant height	Fruit length	Fruit diameter	Fruit weight	Number of fruits per plant	Number of pickings	Number of seeds per fruit	Yield per plant	Ascorbic acid content	TSS
HC-201	-6.26	-1.09	-2.89	0.86	-0.62	-0.59	-15.45	1.59	0.08	-40.28	-57.66	1.92**	0.01
Peprika	0.17	8.17**	2.41**	8.06**	2.11**	-1.32**	-20.90**	3.02**	0.25**	-23.89**	-34.62**	-14.88**	-0.40
CW(N)	-1.81**	4.88**	0.26**	-2.68**	0.34	0.02	8.23**	-0.26**	-0.47**	-20.12**	-16.86**	4.09**	0.04
CW(T)	3.25**	-10.44**	-2.76**	-7.79**	-0.72**	0.70**	8.73**	0.31**	-0.36**	8.78***	10.53***	2.14**	0.08
YW	2.73**	-6.80**	-0.28**	-2.27**	-0.43**	0.09	6.88**	0.51**	0.08	3.32**	24.12**	4.09**	0.62**
SPP	1.84**	3.52**	4.42**	1.61**	0.54**	0.32**	2.74**	0.44**	0.08	12.58**	6.25**	-2.06**	0.01
RC-1	0.07	2.56**	-1.17**	2.20**	-0.68**	0.78**	9.76**	1.37**	0.34**	59.60**	68.24**	4369**	0.20

Table 2: Specific combining ability (SCA) of parent combinations in capsicum (*Capsicum annuum* L.)

Crosses	Days to first harvest	Leaves per plant	Leaf area (cm^2)	Plant height (cm)	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	No. of fruits per plant	No. of pickings	No. of seeds per fruit	Yield per plant (g)	Ascorbic acid content (mg/100 g)	TSS (%)
201xpep	3.67**	19.14**	0.28	17.25**	-1.08**	-0.29	6.96**	0.47	0.15	9.22**	37.22**	-12.96**	0.21
201xcw(N)	5.67**	-22.86**	-2.46**	-31.42**	-4.38**	1.37**	12.78**	-3.73**	0.15	5.92**	-42.22**	23.22**	1.61**
201xcw(T)	5.67**	-61.53**	-14.67**	-37.75**	-1.58**	1.94**	16.86**	-2.93**	0.25	-30.78**	36.98**	20.47**	-0.19
201xYW	5.67**	-3.86**	3.53**	-7.75**	-1.28**	2.04**	18.51**	-2.43**	0.15	13.08**	63.44**	23.72**	0.68
201xSPP	3.67**	16.14**	4.16**	22.42**	1.92**	0.14	18.33*	-4.43**	0.25	2.22**	32.76**	18.06**	0.51
201xRC-1	3.67**	-22.26**	-10.98**	2.58**	-2.38**	2.87**	25.96**	-1.03**	-0.25	189.22**	111.85**	25.84**	0.51
PepxCW(N)	1.22**	6.76**	3.71**	1.06*	-0.84*	-0.25	-0.78**	-1.91**	0.70**	65.76**	-11.39**	-3.52**	0.00
PepxCW(T)	0.78**	-25.25**	0.80**	8.40**	0.83*	0.49*	-13.26**	-0.11**	0.70**	-48.99 **	-20.79**	-3.86**	- 9. 67**
PePxYW	0.78**	-14.54**	-5.44**	9.40**	0.66	0.59**	- 6.30**	-1.21**	0.30	56.06**	-12.89**	10.20**	0.34
PepxSPP	4.88**	-4.54**	0.16	10.40**	-0.17	0.15	122..06**	0.99	0.30	62.36**	35.64**	4.43**	0.47
PepxRC-1	1.22**	-34.24**	-5.34**	7.06**	-3.17**	1.47**	-132	-1.31**	0.70**	122.06**	-16.93**	1.08*	-0.13
CW(N)xCW(T)	7.15**	48.81**	-9.30**	-2.42**	-0.88*	0.67**	-26.62	-1.93**	0.00	132.08**	-104.39**	0.52	-0.26
CW(N)xYW	7.15**	4.41**	11.41**	-2.07**	1.00**	-1.07**	-9.07**	-1.73**	0.40*	29.08**	-10.11**	7.97**	-0.31
CW(N)XSPP	7.15**	-16.59**	4.28**	12.58**	-0.83*	1.57**	21.99**	-0.23	0.40*	26.62**	149.15**	-4.63**	0.19
CW(N)XRC_1	0.15**	38.81**	-11.13**	27.58**	0.83*	-0.20	52.14**	-1.87**	1.40**	0.08	431.16**	8.07**	0.35
CW(T)xYW	-0.74**	18.85**	-16.03**	2.16**	0.42	-0.50*	43.59**	-1.31**	0.20	-9.0**	186.16**	0.49	0.83
CW(T)xSPP	-6.40**	22.13**	17.01**	5.5.5**	-0.58	0.63**	12.99**	-1.78**	0.77**	66..93**	-0.54*	-14.75**	0.66
CW(T)xRC-1	-4.40**	19.41**	-4.63**	8.84**	0.76*	1.00**	28.70**	0.99**	0.37*	84.63**	257.79**	5.25**	0.23
YWxSPP	-3.00**	9.50**	5.08**	6.10**	-1.59**	-0.47*	3.64**	0.66*	0.33	38.69**	487.00**	1.89**	0.26
YwxRC-1	-3.00**	29.80**	6.89**	0.17	0.41	0.96**	2.19**	0.97**	0.33	18.43**	136.20**	0.79	0.77
SPPXRC-1	-2.33**	-2.87**	0.69**	-6.46**	0.49	0.30	24..94**	-1.02**	0.06	55.85**	1 8.87**	3.86**	-0.71

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PER SE PERFORMANCE AND HETEROSIS OF TWO HYBRIDS OF CHILLIES (*CAPSICUM ANNUUM* L.) FOR QUALITATIVE TRAITS IN THREE DIFFERENT SEASONS

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INTRODUCTION

In the recent concept of value addition in the food industry, a hybrid / genotype with high capsaicin and oleoresin content would serve better for international trade since such genotypes would give higher capsaicin and oleoresin yield per unit area. A consistent pungency level is important for processors and consumers. Pungency is one of the most characteristic attributes of the genus Capsicum. In chilli, capsaicin is an important quality trait, which determines the pungency of the produce. Chilli oleoresin, which is prepared from dried chilli powder by solvent extraction, represents the complete flavour or the true essence. So the desirable genotype should possess a low genotype X environmental interaction for quality traits. Keeping this in view, the study was carried out to evaluate the *per se* performance of two F_1 hybrids for quality traits in three different seasons.

MATERIALS AND METHODS

The female parents CA 86 – 1 and CA 86 – 2 are two single plant selections made from the genotype CA 86 which is a local type collected from Sadayampatti a village near Sattur in TamilNadu. The accession CA 86 has already been adjudged as a good female parent and CA 84 another local type collected from Ramanathapuram was adjudged as good male parent (Anandanayaki, 1997). By using these three parents two hybrids namely Hybrid 1 (CA 86 –1 X CA 84) and Hybrid 2 (CA 86 –2 X CA 84) were developed and evaluated for quality traits in a Randomized Block Design in three different seasons (June 2000 – November 2000, October 2000 – March 2001 and December 2000 – May 2001) at Horticultural college and Research Institute, TNAU, Coimbatore. Heterosis over mid-parent, better parent and best parent were calculated by adopting the procedure of Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Per se performance for all the quality traits were higher in hybrids than their parents (Table 1). In case of heterosis, hybrid 1 showed highly significant positive heterosis over mid, better and best parents in all the three seasons (Table 2) for all the traits. Expression of better value by Hybrid 1 than the better parent for ascorbic acid content may be due to overdominance or it may be due to mutual cancellation of epistatic genes present in the parents. In Hybrid 2, the genes contributed by P_2 under the genetic background of P_3 may have more interaction with environment. Hence though the hybrid 2 exhibited a highly significant positive heterosis over mid and better parents in all the three seasons it showed negative heterosis over the best parent in the third season. Positive and negative heterosis for ascorbic acid content was also found by Saraladevi (1994) and Anandanayaki (1997).

In chilli, capsaicin is an important quality trait, which determines the pungency of the produce. In the recent concept of value addition in the food industry, a high capsaicin hybrid / genotype would serve better for international trade since such genotypes would give higher capsaicin yield / unit area. In the Hybrid 1, P_3 would have contributed to better capsaicin content. But in Hybrid 2 capsaicin content was brought down due to the influence of the parent P_2 that had the lowest capsaicin content both in the green and dry fruits. In the case of heterosis, Hybrid 1 showed highly significant positive heterosis over mid, better and best parents in all the seasons. The earlier reports by Sharma and Saini (1977), Sekar (1984), Anandanayaki (1997) and Doshi and Shukla (2000) lend support to the present findings. Heterobeltiosis expressed by Hybrid 1 for capsaicin content in both green and dry fruits may be due to additive X additive gene interaction while partial dominance would have operated in the Hybrid 2.

The colour value of the dry fruits within the parents did not vary much in different seasons. In Hybrid 1, partial dominance was seen for P_1 to operate in the direction of increasing the fruit colour. But in the Hybrid 2, low x low *per se* parents resulted in a very low *per se* hybrid. This would have been by the additive x additive gene interaction resulting in further reduction in colour value. High *per se* X low *per se* parents yielding intermediate *per se* hybrid like Hybrid 1 may be due to additive – dominant gene interaction. Positive and negative heterosis for colour value was also observed by Anandanayaki (1997).

Oleoresin is yet another important quality trait of value addition in chilli. The Hybrid 1 was a high *per se* cross of low x low per *se* parental combination, which might have resulted from non-additive gene interaction of epistatic nature in the parents. While Hybrid 2 might have been a resultant of additive – dominant gene interaction among the parents. The positive heterosis over mid parent may be due to partial dominance. Anandanayaki (1997) observed highly significant positive heterosis over mid and better parents and also highly significant negative heterosis over mid, better and best parents in different hybrids for this trait. She also reported that none of the hybrids exhibited significant positive heterosis over the best parent.

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Table 1. ***Per se*** **performance of parents and hybrids for fruit quality characters in three different seasons**

Parents/ Hybrids	Ascorbic acid content (mg/100g of fruit)		Capsaicin content (g/100 g of fruit)		Colour value of dry fruits ASTA units	Oleoresin content of fruit (%)
	Green fruit	Dry fruit	Green fruit	Dry fruit		
I season						
P_1	237.0	162.0	0.681	0.549	28.20	11.22
P_2	220.3	137.3	0.585	0.455	24.87	13.80
P_3	215.8	152.0	0.682	0.553	22.61	11.57
Hybrid 1	257.3	179.0	0.753	0.682	27.77	14.60
Hybrid 2	239.0	169.5	0.690	0.590	21.87	12.80
II season						
P_1	235.6	160.4	0.673	0.548	28.00	11.20
P_2	220.7	139.0	0.566	0.450	24.26	13.24
P_3	209.8	150.3	0.677	0.551	22.65	11.22
Hybrid 1	258.1	179.4	0.751	0.680	27.83	14.58
Hybrid 2	237.7	165.1	0.684	0.584	21.28	12.68
III season						
P_1	237.8	160.8	0.684	0.548	28.15	11.24
P_2	221.3	137.3	0.583	0.458	24.86	13.79
P_3	216.3	152.0	0.683	0.549	22.48	11.54
Hybrid 1	257.3	179.3	0.752	0.682	27.77	14.61
Hybrid 2	237.3	168.0	0.691	0.588	21.87	12.78
Pooled analysis						
P_1	236.8	161.0	0.679	0.548	28.12	11.22
P_2	220.7	137.8	0.578	0.454	24.66	13.61
P_3	213.9	151.4	0.681	0.551	22.58	11.44
Hybrid 1	257.5	179.2	0.752	0.681	27.79	14.60
Hybrid 2	238.0	167.5	0.688	0.587	21.67	12.75
Mean of Parents	223.8	150.1	0.646	0.518	25.12	12.09
Mean of Hybrids	247.8	173.4	0.720	0.634	24.73	13.68
Mean	233.4	159.4	0.676	0.564	24.96	12.72
SE	1.58	1.10	0.0021	0.0023	0.044	0.007
$CD_{(p=0.05)}$	3.44	2.40	0.0047	0.0050	0.096	0.016
$CD_{(p=0.01)}$	4.83	3.37	0.0065	0.0070	0.134	0.022

Table 2. Heterosis over mid-parent (d_i), better parent (d_{ii}) and the best parent (d_{iii}) in three different seasons for quality characters

Characters	Hybrid 1			Hybrid 2		
	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
I season Ascorbic acid content in green fruit	13.64**	8.54**	8.54**	9.63**	8.51**	0.84
Ascorbic acid content in dry fruit	14.01**	10.49**	10.49**	17.20**	11.51**	4.63**
Capsaicin content in Green fruit	10.49**	10.41**	10.41**	8.92**	1.17*	1.17*
Capsaicin content in dry fruit	23.77**	23.33**	23.33**	17.06**	6.69**	6.69**
Colour value of dry fruit	9.29**	-1.55**	-1.55**	-7.86**	-12.04**	-22.44**
Oleoresin content of dry fruit	28.20**	26.27**	5.80**	0.92**	-7.26**	-7.26**
II season Ascorbic acid content in green fruit	15.91**	9.55**	9.55**	10.42**	7.68**	0.86
Ascorbic acid content in dry fruit	15.51**	11.86**	11.86**	14.18**	9.88**	2.95**
Capsaicin content in Green fruit	11.26**	10.93**	10.93**	10.06**	1.03*	1.03*
Capsaicin content in dry fruit	23.75**	23.41**	23.41**	16.68**	5.99**	5.99**
Colour value of dry fruit	9.91**	-0.60**	-0.6**	-9.30**	-12.31**	-16.2**
Oleoresin content of dry fruit	30.12**	30.00**	10.14**	3.71**	-4.22**	-4.22**
III season Ascorbic acid content in green fruit	13.33**	8.20**	8.20**	8.46**	7.23**	-0.21
Ascorbic acid content in dry fruit	14.63**	11.51**	11.51**	16.16**	10.53**	4.51**
Capsaicin content in Green fruit	10.02**	9.94**	9.94**	9.16**	1.17**	1.02*
Capsaicin content in dry fruit	24.34**	24.23**	24.23**	16.78**	7.10**	7.10**
Colour value of dry fruit	4.77**	-1.36**	-1.36**	-7.60**	-12.02**	-22.30**
Oleoresin content of dry fruit	28.24**	26.58**	5.92**	0.91**	-7.32**	-7.32**
Pooled analysis Ascorbic acid content in green fruit	14.28**	8.76**	8.76**	9.50**	7.81**	0.50
Ascorbic acid content in dry fruit	14.72**	11.29**	11.29**	15.84**	10.64**	4.03**
Capsaicin content in Green fruit	10.60**	10.49**	10.49**	9.38**	1.13**	1.13**
Capsaicin content in dry fruit	23.98**	23.71**	23.71**	16.82**	6.57**	6.57**
Colour value of dry fruit	9.63**	-1.17**	-1.17**	-8.26**	-12.12**	-22.94**
Oleoresin content of dry fruit	28.86**	27.62**	7.27**	1.80**	-6.32**	-6.32**

* Significant at 5 per cent level

** Significant at 1 per cent level

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GENETIC DIVERGENCE IN HOT CHILLI (*CAPSICUM CHINENSE* JACQ.)

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INTRODUCTION

Hot chilli (*Capsicum chinense* Jacq.) is characterized by a typical flavour and aroma and noted for the high oleoresin and capsaicin content. Breeding crop plants adopting hybridization as a tool is one of the most important crop improvement methods. The success of hybridization programme is mainly dependent on the genetic diversity of the parents chosen. Kerala is blessed with diverse soil and climatic conditions that have helped in the development of different landraces of hot chilli having wide genetic divergence. Since very little work has been done in this species, an effort was made to assess the genetic divergence among the available hot chilli landraces of Kerala.

MATERIALS AND METHODS

This experiment was carried out at the College of Agriculture, Kerala Agricultural University, Thiruvananthapuram, Kerala, India, during 2000 –2001. The materials for the study consisted of 32 accessions of hot chilli collected from different parts of Kerala, India. The experiment was conducted in randomised block design with three replications. Ten plants were maintained per plot. All the recommended cultivation practices were followed to raise the crop under irrigated condition. Five plants were selected randomly from each accession and observations were recorded on plant height, days to first flowering, pollen viability, fruits per plant, fruit weight, seeds per fruit, number of harvests, ascorbic acid content, mosaic incidence and yield per plant. The genetic divergence was estimated using the D^2 statistics of Mahalanobis (1928) and the genotypes were grouped on the basis of minimum generalized distance using the method suggested by Tocher (Rao,1952).

RESULTS AND DISCUSSION

The analysis of variance showed significant differences among the accessions for all the ten characters studied.

Based on D^2 analysis, the 32 accessions were grouped into six clusters (Table 1). Cluster I was the largest with 21 accessions, followed by cluster II with six and cluster III with two accessions. Clusters IV, V and VI had one accession each, as these could not be clubbed with any other accession. Clustering of different genotypes of chilli (*Capsicum annuum* L.) based on genetic distance was done by several workers (Sundaram *et al.*, 1980; Gill *et al.*, 1982 and Varalakshmi and Haribabu, 1991).

The intracluster distance was on the increase with increasing cluster size. Cluster I had the highest intracluster distance (229.93), followed by cluster II (217.55) and cluster III (188.74) (Table 2). The minimum intracluster distance (0.0) was recorded for cluster IV, V and VI as they contained only a single accessions each. The study revealed maximum divergence between cluster I and VI, followed by clusters I and V as shown by their high intercluster distances (1965.74 and 1640.10 respectively). Cluster V and VI with least divergence (339.74) showed a closer relationship between the accessions included. Based on genetic distance, accessions of cluster V and VI may be used for hybridization with selected accessions of cluster I as crossing between divergent parents is likely to produce wide variability and transgressive segregants with high heterotic effects.

Comparison of cluster means for different characters revealed considerable differences between the clusters (Table 3). Cluster IV consisted of taller accession which was late in flowering, whereas cluster V comprised of early flowering accession, which had the maximum number of harvests and least incidence of mosaic. Cluster III had maximum pollen viability, fruit weight and ascorbic acid content. Yield per plant, fruits per plant and seeds per fruit were highest in cluster VI. To get recombinants with high yield potential, selection in clusters V and VI can be practiced as it contains only one seed source and has mean values higher for the traits under study. For crop improvement in chilli, intercrossing among accessions with outstanding mean performance was suggested by Indira (1994) and Roy and Sharma (1996). Among the characters studied, fruits per plant and yield per plant were the potent characters contributing maximum divergence and playing dominant role in the yield improvement of *Capsicum chinense*.

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Table 1. Clustering pattern of accessions of *Capsicum chinense*

Cluster No.	Number of accessions	Accessions
I	21	CC 14, CC 6, CC 9, CC 21, CC 18, CC 10, CC 25, CC 26, CC 17, CC 24, CC 32, CC 19, CC 20, CC 29, CC 4, CC 1, CC 8, CC 22, CC 11, CC 3, CC 16
II	6	CC 28, CC 30, CC 15, CC 31, CC 27, CC 12
III	2	CC 2, CC 7
IV	1	CC 5
V	1	CC 13
VI	1	CC 23

Table 2. Mean inter and intracluster distances

Cluster	I	II	III	IV	V	VI
I	230	749	1.148	389	1.640	1.966
II		218	448	396	941	1.256
III			189	790	560	852
IV				0	1.280	1.606
V					0	340
VI						0

Diagonal elements - intracluster values; Off diagonal elements- intercluster values

Table 3. Cluster means of ten biometric characters

Cluster	Plant height (cm)	Days to first flowering	Pollen viability (%)	Fruits per plant	Fruit weight (g)	Seeds per fruit	Yield per plant (g)	Number of harvests	Ascorbic acid (mg/100g)	Mosaic incidence (V.I.)
I	93	72	57	97	4.3	28	213	3.4	94	56
II	111	70	77	223	6.2	39	710	5.5	105	56
III	114	65	80	285	7.5	46	990	4.7	115	52
IV	116	77	43	201	6.5	28	480	6.5	95	52
V	105	55	80	620	5.2	42	1436	6.9	103	41
VI	102	61	79	637	5.9	48	1650	5.9	103	50
Contribution towards total divergence (%)	8.19	12.07	22.88	66.51	18.49	22.23	60.81	23.14	7.60	11.23

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DEVELOPMENT OF DISEASE RESISTANT HOT PEPPER HYBRIDS SUITABLE FOR PROCESSING

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INTRODUCTION

Chilli (*Capsicum annum* L.) is one of the most valuable commercial spice crop grown on 0.95 million hectares in India with a total production of 0.82 million tonnes (Peter, 1999). The chilli is a rich source of ascorbic acid and used in salad and as well as in curries. The red fruit are characterized by its pungency and colouring matter. The quality of any chilli hybrid when judged by the grower give priority to yield, fruit colour and lack of disease (viruses) and pests. As the produce (chilli fruits) moves through market channels other quality parameters are recognized particularly processing quality, nutritional quality, appearance and storage quality. The two major diseases viz. leaf curl virus and wilt posses threat to the chilli crop in India, though CMV, TMV and other viruses do occoure on this crop. These diseases reduce productivity and quality of the crop. Keeping in view the importance of this crop and the problems of growers, number of hybrids were attempted and the promising one's were evaluated and identified which were disease resistant and rich in dry matter, capsaicin and colouring matter.

MATERIALS AND METHODS

The studies were carried out in the research experimental field of the department of Vegetable Crops, Punjab Agricultural University, Ludhiana during the Rabi season 2002-03. Randomized block design was followed with three replications. Fifteen plants were grown in each replication at spacing of 60x45 cm. The seeds were sown in the last week of October 2002 in the nursery and seedlings were transplanted in the field in the second week of February 2002. The fertilizer and plant protection measures who followed as per the package and practice of Punjab Agricultural University.

The total yield at red ripe fruits stage was recorded. The leaf curl percent infection was recorded at the last picking stage. The quality characters viz. dry matter (%), capsaicin (%) and colouring matter (ASTA) were analyzed by taking red ripe fruits samples uniformly from the second harvest. For the capsaicin estimation the method suggested by Bajaj and Kaur (1979) was followed,

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whereas colouring matter estimation from the red ripe fruits was done by the method suggested by Rosebook *et al* (1968). Dry matter content was determined by drying the chilli at 60±2°C to a constant weight. The hybrids evaluated were synthesized by using genic male sterile line (MS-12) as female and the elite material developed as male parents. These were evaluated along with two check hybrids CH-1 and CH-3.

RESULTS AND DISCUSSIONS

The persual of the analysis of variance revealed significant difference for red ripe fruit yield (Table 1). Based on the estimates of average mean value for dry matter (%), Capsaicin (%), and Colouring matter (ASTA) indicates wider genetic variability for these quality characters and also for leaf curl incidene (%) (Table 1). There was no hybrid, which was significantly superior than CH-3 check hybrid for red fruit yield, however, the hybrid CH-35 was observed to be highest yielder followed by CH-39 (Table 1). The only hybrid CH-35 was significantly superior than the check hybrid CH-1 but the leaf curl incidence was low in CH-39 (13%) as compared to CH-3 (27%), CH-1 (10%) and CH-35 (22%). The other hybrids where the leaf curl incidence was low were CH-10 (4%), CH-3 (13%) and CH-33 (18%).

The red fruit yield per hectare ranged from 252.7 q/ha to 476.0 q/ha. The percent leaf curl incidence on different hybrids evaluated ranged from 4.0 to 47.0 (Table-1). Similarly for the quality character particularly the colouring matter is considered to be very important as the ASTA colour value effect the quality of the processed product of chilli. In the present studies there was a wide range of variability for colouring matter of red ripe fruits ranging from 102.1 ASTA to 228.6 ASTA. The hybrids CH-35 (228.6 ASTA) and CH-16 (205.3 ASTA) are identified ideal for processing keeping in view their colour value as it effect on the brightness or richness of the final product. The colouring matter of check hybrids CH-1 (147.6 ASTA) and CH-3 (163.3 ASTA) is comparatively lower than that of CH-35, CH-16 and CH-39 (TABLE 1). Since colour has been one of the major criteria used for quality assessment of capsicum and has been employed as an index of maturity therefore CH-35 and CH-16 is considered to be ideal for processing. Bajaj *et al* (1980) conducted such studies on chilli varieties and reported maximum colouring matter (118.6) in powder, however, very low colouring matter (82 ASTA to 94 ASTA) range was reported to chilli varieties by Reddy *et al* (1999).

The capsaicin content, an important quality parameter for pungency level was also estimated. It ranged from 0.30% to 0.80%. The highest capsacin content was observed in check hybrid CH-1 and CH-35 (0.80%) followed by CH-11, CH-30 and CH-33 where it was 0.71% (Table 1). More recently the consumers prefer chilli genotypes with low pungency. In the present studies CH-29 was observed to be a suitable hybrid with low pungency possessing capsaicin content of 0.30% followed by CH-26 (0.42%), CH-20 (0.44%) and CH-21 (0.44%) (TABLE 1). The CH-39 a high yielding hybrids with very high

colouring matter is identified as suitable for growers and processors because it posses low capsaicin (0.45%) compare to check hybrids, CH-1 and CH-3 (Table.1). Earlier wide range of genetic variability in chilli for capsaicin was reported by many workers (Sharma and Saini, 1977, Bajaj *et al* (1978) and Govinda Reddy *et al* 1999.

The dry matter (%) was highest in CH-17 (18.7%) followed by CH-35 (18.3%) and CH-13 (17.8%). Dry matter being an important character and if in totality to see the quality of all hybrids only the CH-35 was observed to be the ideal for yield, dry matter, colouring matter and capsaicin content. Each of these quality component posses immense important from commercial point of view as capsaicin content for pharmaceutical preparation, colouring matter used in colour enhancement and dry matter for Chilli paste and powder (Purseglove *et al* 1981).

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TABLE 1 YIELD AND QUALITY CHARACTERS OF CHILLI HYBRIDS ALONG WITH DISEASE REACTION

Hybrid	Yield (Red fruits) q/ha	Leaf curl incidence (%)	Wilt	Dry matter of red fruits (%)	Capsaicin of red fruits (%)	Colouring matter of red fruits (ASTA)
CH-1 (Check)	342,9	20	R	17,6	0,80	147,6
CH-2	348,3	32	S	14,2	0,53	103,0
CH-3 (Check)	398,5	25	R	13,7	0,61	163,3
CH-4	395,8	20	R	15,1	0,64	137,8
CH-6	39,04	26	R	14,9	0,53	128,4
CH-7	333,7	23	R	15,3	0,63	146,4
CH-9	345,6	47	T	14,1	0,63	102,1
CH-10	305,1	4	R	16,2	0,82	121,7
CH-11	367,2	20	S	15,0	0,71	158,9
CH-13	322,1	28	S	17,8	0,58	121,4
CH-15	330,2	32	R	13,8	0,50	113,3
CH-16	372,6	32	T	12,9	0,50	205,3
CH-17	254,6	35	HR	18,7	0,50	111,6
CH-20	381,5	33	S	15,9	0,44	110,2
CH-21	386,9	35	S	16,0	0,44	153,2
CH-22	252,7	35	S	11,9	0,60	147,8
CH-23	328,3	33	T	14,9	0,64	145,6
CH-24	374,2	23	R	11,4	0,63	127,7
CH-26	318,6	30	S	12,2	0,42	130,9
CH-29	363,4	28	S	13,8	0,30	155,3
CH-30	330,2	13	HR	15,8	0,71	155,3
CH-33	342,9	18	HR	11,6	0,71	133,3
CH-35	476,01	22	T	18,3	0,80	228,6
CH-39	439,02	13	HR	14,5	0,45	173,0
CD5%	117,4	--	--			

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YIELDING OF *Capsicum frutescens* L. SOFT-FLESH BREEDING FORMS

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Introduction

The research carried out in our unit concerning *Capsicum frutescens* L. refers to, among others, genetic improvement of soft-flesh forms, Processing usability of such genotypes is connected with possibility of their use for the production of juice or concentrates. The process of production of such products does not require application of high temperatures which have an adverse impact on the content as well as quality of biologically active substances, since it is possible to mechanically separate edible parts from those inedible, thus gaining a product of high homogeneity.

The soft-flesh feature is of monogenic character and is conditioned by the dominant gene *S* (Lippert et al. 1965). This means that it may be easily included into the hard-flesh forms and expressions thereof may be also observed in heteroallelic hybrid forms F_1. What is also essential here, is the fact of pleiotropic influence of allele S, phenotypically characterized with very smooth separation of pericarpium from pedicel and flower bottom. Thus, fruit may be shaken off plants.

What decides on the possibilities of the use of soft-flesh fruit as a raw material in processing industry is the content of sugar, vitamins, flavonoids and carotenoids. What is essential for the pharmaceutical industry is the concentration of capsaicinoids (Wall and Bosland 1998). If the product is to be of nutraceutic character, essential is the content of all the biologically active components.

Industrial utilization of the said raw material depends on the possibilities of initialization of its production. This in turn depends on plant yielding, yield features and fruit biological performance. The presented article covers initial assessment of some of the soft-flesh *C. frutescens* L. type genotypes obtained by us.

Materials and methods

The research material presented in this article were three selected by random plants of two selected soft-flesh populations of *C. frutescens* L. Each population consists of 40 plants. Selection was carried out by means of a pedigree method with estimation of progenies since 1997. These populations, within each of them, demonstrated very high rate of phenotypical similarity. The data presented in diagrams are of 2003 and refers to plants grown in unheated foil tents with density of 4.5 plants/m^2. Fruit crop was single and covered physiologically ripe fruit. All of them were characterized with intensive dark red colour. Biotechnological weight denoting edible weight part of the fruit was determined after its separation from inedible part, i.e. placenta with seeds and peel. The results were analysed statistically. The data on figures marked by the same letter are similar from statistical point of view by P = 95%.

Results and discussion

Plant crop was presented with the use of two criterion, i.e. crop amount of physiologically mature fruits and the number of such fruits from one plant (fig. 1, 2). Comparison of the results suggests that yielding within populations was similar. No significant statistic variances between plants representing both populations were stated. Referring to the number of fruits, the results were more differentiated. A definitely lesser number of fruits was collected from plant 1/2.

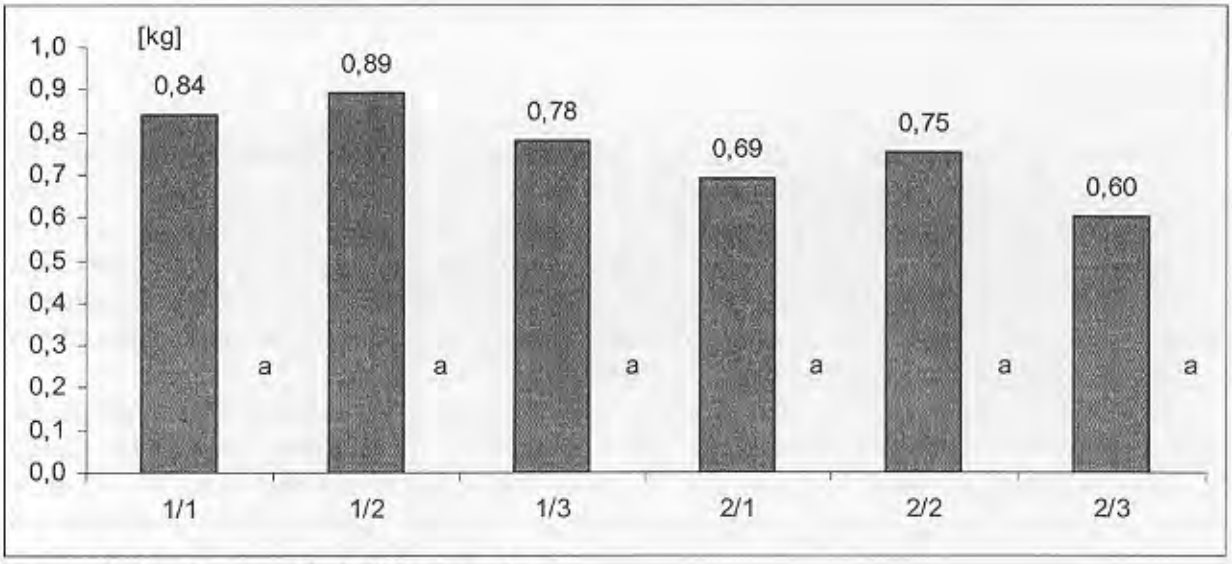

Fig. 1. Yield of mature fruit in kg per plant

It is difficult to refer the obtained results to other experiments due to missing information on the use of soft-flesh forms as the raw material for processing industry and pharmaceutical industry. However, it is worth to verify the same within the scope of practical significance. However, this is not easy, particularly when a reference is made to selected information on yield within *Capsicum*. Namely, it is possible to obtain yield in the amount of

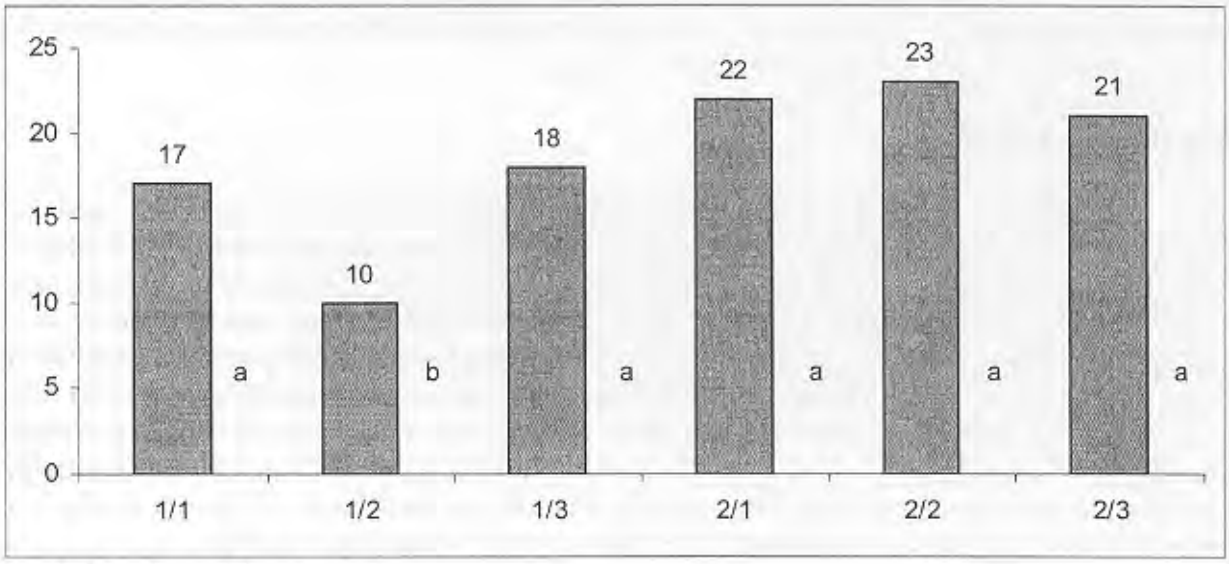

Fig. 2. Number of fruit per plant

over 10 kg from one square meter in case of foil tent growing, and also 0.3 kg/m^2 in open field (Stepowska and Kosson 2003, Alegbejo and Orakwue 2002). In the experiments carried out by Sreelathakumary and Rajamony (2003) the yield of *C. frutescens* L. 20 accessions from Kerala hesitated between 65-270g of fruits per plant.

Soft-flesh fruits are a tough commercial product. The use of them in the market of fresh vegetables is difficult. As mentioned first in above, they may be a raw material for the production of biologically active food products, to mention nutraceutics among others. In this case, however, a relevant fruit output is required. For the purpose of such crop usage and its assessment we have introduced a determination – biotechnological weight. This is the weight of pericarpium excluding placenta, seeds, and peel. The figure 3 shows the data referring to

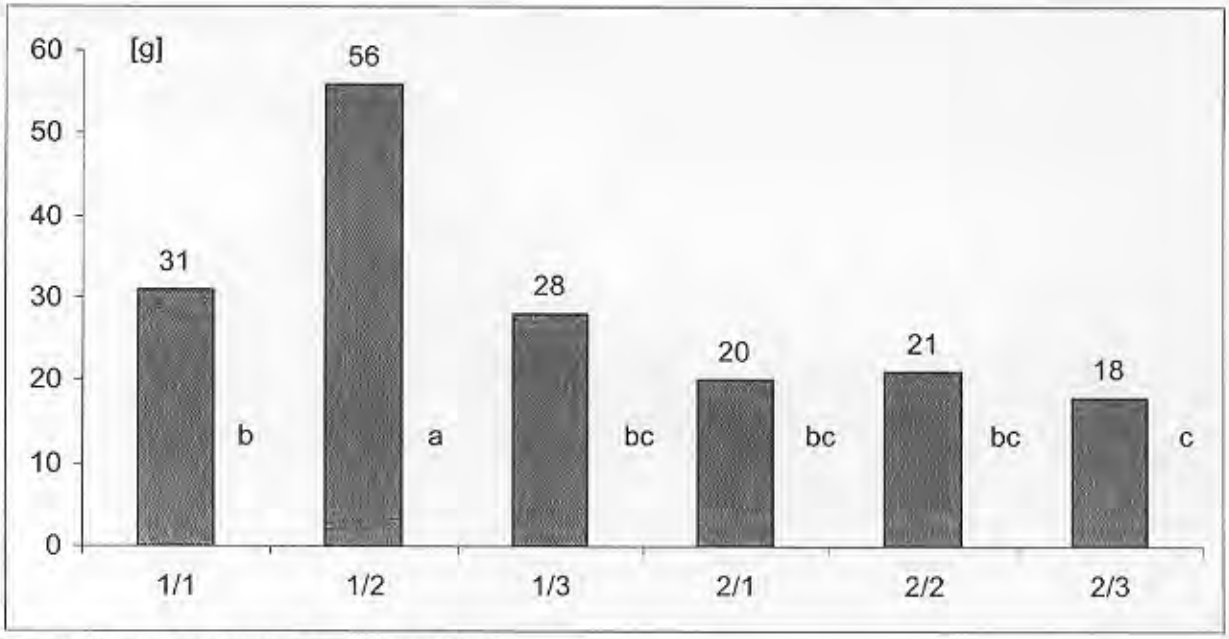

Fig. 3. Biotechnological weight of fruit

this feature. It turned out that differentiation in its range was higher than for an absolute amount of crop. Thus, this indicates possibility of selection of forms of various biotechnological performance. Initial observations demonstrate that this type of fruit performance decreases along with the decrease of mean fruit weight. Knowing fruit biotechnological weight as well as their number on one plant it is easy to determine net output of obtained crop. In case of hard-flesh forms (Wang and Wang 1996), very high differentiation of the share of edible part in total fruit weight is also observed. However, in this case the fruit peel is recognized as an edible part.

Further work on soft-flesh forms will concentrate on determination of the dependency between fruit weight and biotechnological performance of the same, fruit crop yield and the crop of fruit edible parts. What is also necessary is the determination of optimal fruit mean mass due to the problems connected with cropping and transportation of soft fruits. Furthermore, raw material standardization with reference to the content of capsaicinoids will addressed as well.

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INCOMPLETE ANTHOCYANINLESS MUTATIONS IN *CAPSICUM ANNUUM* L. X *C. CHINENSE* JACQ. HYBRIDS

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Abstract: Uniform colour mutations were found in the segregating progenies of interspecies hybrids *C. annuum* x *C. chinense* after one backcross with C. *annuum*. Two fully anthocyanin *C.annuum* forms, cv. 'Zulu' and f. *nigrum* Smith (genes *A, Mo-A*) were used as female parents. They were pollinated respectively with *C. chinense* accessions No 23 and PI 315008 which differ in purple coloration. PI 315008 possesses considerable anthocyanin amount in stem and fruits. No 23 has anthocyaninless stem, sometimes with anthocyanin shades on the nodes and light-green fruits. Uniform white-greenish flowers, purple stamens and stigma are presented in both *chinense* forms. F_1 plants were backcrossed once with anthocyaninless *C. annuum* cv. 'Albena' or line Vibo (gene *al*). Single plants were found in the segregating progenies of BC_1 of both hybrid combinations with anthocyaninless light green stems and foliage, flowers with very pale purplish-cream petals, purple stamens and stigma and light purple fruits on ivory background. Separate plants with anthocyaninless olive green stem and leaves, flowers with purplish petals, filaments, stigma, blue anthers and anthocyanin-spotted olive green immature fruits were also observed in *C. annuum* x *C. chinense* PI 315008 hybrid. Their progenies stably maintained mutant phenotype after self-pollination. Possible gene control of incomplete anthocyaninless mutations is discussed.

Keywords: *Capsicum annuum*, *C. chinense*, interspecific hybridisation, anthocyanin expression, anthocyaninless mutations

INTRODUCTION

The 'normal' phenotype of *Capsicum annuum*, consisting of white petals, purple or blue anthers and nodes, and colourless filaments and styles, is controlled by the gene *al*$^+$ according to the description of Lippert et al. (1965). The recessive *al* gene affects anthocyanin-less mutations. They have been found by Deshpande, Odland (Lippert *et al.*, 1966) and Daskalov (1973). Five other *C. annuum* mutations (*al-1* to *al-5*), not allelic with each other and with Daskalov's mutant, incorporated in cv. 'Albena', as well as two (*al-6* and *al-7*) in *C. chinense* and one (*al-8*) in *C. chacoense* have been described by Csillery (1980, 1983). They all have green hypocotyls and stem nodes, yellow anthers and no purple spots on immature fruits. Purplish spots could occasionally appear on the nodes and fruits of some genotypes, especially in cold and rainy weather (Daskalov and Poulos, 1994). A slight purplish marking along the line of dehiscence has been also observed in *al-5* (Csillery, 1980).

An incompletely dominant gene *A* controls the anthocyanin colour of stem, foliage, flowers and immature fruits. In *AA* genotypes its action is intensified by a gene-modificator *Mo-A*, being ineffective alone (Lippert *et al.*, 1966, Pochard, 1977).

Additional genes for differential anthocyanin accumulation in flower (*C*, R_1 and R_2), style (*As*), style and filaments (*Asf*) and immature fruits (*F*) have been also reported, some of them redesignated (Lippert *et al.*, 1966) or eliminated (Daskalov and Poulos, 1994).

MATERIAL AND METHODS

Two completely anthocyanin small-fruited *C. annuum* forms (cv.'Zulu' and f. *nigrum* Smith) were used as female parents. They had dark purple stems, foliage, flowers and fruits (genes *A* and *Mo-A*). Interspecific hybridisation was realised with two *C. chinense* accessions as pollinators. PI 315008 contains considerable amount of anthocyanin on stem, petioles, sepals, calyx base and on immature ivory-coloured fruits. No 23 has anthocyaninless stem, sometimes with anthocyanin traces on the nodes and light-green fruits. Both specimens are with uniform creamy-greenish flowers and purple anthers, filaments and styles. F_1 hybrids were backcrossed once with anthocyaninless (gene *al*) *C. annuum* mutants (cv. 'Albena' and line Vibo), originating from local kapya-type variety 'Zlaten medal'. Plants are anthocyanin free, with light green stems and foliage and white flowers with yellow anthers. They differ in colour of immature fruits, pale green for cv. 'Albena' and sulphury white for line Vibo.

F_1 and BC_1 plants were grown in pots, in a greenhouse and the segregating progenies – in field conditions. Colour of the different plant organs was visually determined.

RESULTS AND DISCUSSION

In F_1 of both hybrid combinations *C. annuum* f. *nigrum* Smith x *C. chinense* PI 315008 and C. *annuum* cv. 'Zulu' x *C. chinense* No 23 the anthocyanin was spread in all plant parts, but in smaller intensity than in *nigrum* parents, because of the incomplete dominance of *A* and the inactivation of *Mo-A*, being effective in AA genotypes only (Lippert et al., 1966). 12 plants were obtained after one backcross of F_1 *nigrum* x 315008 with line Vibo, falling into two groups according to stem coloration intensity. Six of them had purple spots in the nodes only. The rest were with purple vascular bundles or with fully anthocyanin stems. Segregation of 7:5 was observed for the presence/absence of antohcyanin in petals, filaments and stigma as well as 9:2 for antohcyanin/antohcyaninless immature fruits. Only three plants were obtained after one backcross of 'Zulu' x No 23 F_1 hybrid with cv. 'Albena', segregating 2:1 for whole stem/stem node coloration, for antohcyanin/antohcyaninless petals, filaments and stigma, as well as for non purple/purple immature fruits. Despite the insufficient number of BC_1 plants, the lack of uniformity in the distribution of anthocyanin suggests the participation of more genes, controlling this process. Anthocyanin expression was investigated in F_2 and F_3 of BC_1 plants with almost 'normal' and with intense coloration, separately grown as siblings. More uniform segregation was observed in these originating from plants with pronounced purple colour. They could be conventionally separated in two groups, one preserving intense coloration with variations and anthocyaninless one (probably one or more genes, controlling anthocyanin presence/absence being homozygous). Wide range of anthocyanin pigmentation was observed in the progenies of almost 'normal' plants,

from dark purple ones, through varying distribution and intensity of the purple colour on plant parts, to anthocyaninless individuals, an indication for the heterosigosity of the initial BC_1 forms. Two plants were found in *nigrum* x 315008 'normal' progenies and one, originating from 'Zulu' x No 23, with uniform mutant phenotype. They were with anthocyaninless light green stems and foliage, flowers with very pale purplish-cream petals, purple stamens and stigma and light purple fruits on ivory background. Another two plants with anthocyaninless olive green stem and leaves, flowers with purplish petals, filaments and stigma, blue anthers and purple-spotted olive-green immature fruits were also observed in *nigrum* x 315008 hybrid. The plants were self-pollinated. Their progeny stably maintained mutant phenotype.

According to the literature, *al* gene prevents the expression of anthocyanin in any plant organ (Lippert *et al.*, 1966; Daskalov and Poulos, 1994). On the other hand the availability of anthocyanin in petals, filaments, stigma and fruits in plants with anthocyaninless stems and foliage suggests an activation of *A* gene. However, it is known that this gene is effective only in the presence of al^+ (Lippert *et al.*, 1966). One of the possible reasons for the appearance of incomplete anthocyaninless mutations is the existence of differential gene control of anthocyanin expression and prevention in *C. chinense,* e.g. partial action of *A* gene (another gene) in the presence of *al*, which could also explain the almost full lack of anthocyanin except flower coloration in No 23.

Another feasible explanation is based to the recent investigations of Chaim *et al.* (2003) and Paran *et al.* (2003). Using *C. annuum* x *C. chinense* hybrids as initial material they map *A* locus to chromosome 10 of *C. annuum* and suspect the possible localisation of genes *A* and *Fc* (filament colour) to this locus, being allelic. *An2* (*A* gene in petunia) is another likely candidate for the latter locus. These authors also suppose that the differential accumulation of anthocyanin in various organs of pepper plants is most probably controlled by a series of alleles at the same locus. Similar mechanism could exist for differential prevention of anthocyanin expression in stem, foliage, flowers and fruits of pepper plants, controlled by a series of alleles/genes with specialised inhibitory function, localised at *al* locus/other loci.

Incomplete anthcyaninless mutations obtained will be included in hybridisation program in order to investigate the inheritance of mutant phenotypes. The results will give more information about the mechanism, controlling the presence and absence of anthocyanin pigment in pepper.

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STABILITY OF AVRDC'S CYTOPLASMIC MALE STERILE (CMS) PEPPER LINES GROWN UNDER LOW TEMPERATURES

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Introduction

Male sterility can dramatically reduce the cost of hybrid seed production by eliminating the task of emasculation. Although CMS in pepper (*Capsicum annuum* L.) has been known since Peterson's discovery in 1958, it has found little commercial utilization, except in the production of hot pepper hybrids in Korea (Shifriss, 1997) and recently in China. Restorer lines are quite common in hot peppers, but less frequent in sweet peppers (Kumar et al., 2001; Zhang et al., 2000; Yazawa et. al., 2002) and seed companies have largely utilized genic male sterility to facilitate the production of hybrid seed. Researchers have reported that CMS pepper lines frequently display unstable sterility under low temperatures (Shifriss and Guri, 1979, Shifriss, 1997, Daskalov, 1998). Commercial use of CMS requires highly stable male sterility, to assure genetically uniform F_1 hybrid seed production, and reduce the risk of incomplete pollen sterility in temperate or mountainous regions where growing conditions may be relatively cool. AVRDC has over several years incorporated the CMS trait into several hot and sweet pepper backgrounds, for use in a wide range of climates. In this experiment, CMS lines in different varietal backgrounds were screened during the winter season of 2002 to identify the most stable male sterile varieties. Pollen viability, anther dehiscence, and selfed seed production under winter production conditions were evaluated.

Materials and Methods

Twenty CMS pepper lines developed at AVRDC were screened under field, screenhouse, and greenhouse conditions at AVRDC (Shanhua, Taiwan, 23° N latitude, 50 m.a.s.l.) during the winter season 2002-3. Because of low populations, and/or late flowering, 5 lines are omitted from this report (Table 1). The original parental A-lines, PBC646 ('Suwon cms'), and PBC644 ('Seungchon cms') were donated by National Horticultural Research Institute of Korea. Six hot pepper varieties had been crossed with one or the other CMS source, and advanced through at least six backcross generations to incorporate the male sterile ((S) rf rf) genotype (CCA 4757, -4758, -4759, -4760, -4916, and –4917). New recurrent parent cultivars were crossed with one of these BC_6 A-lines (CCA 4759) and backcrossed three times. All of these lines have shown stable male sterility in AVRDC greenhouse trials in summer and autumn production seasons. Fertile maintainer lines ((N) rf fr) of all recurrent parents were also grown as checks.

Seeds of the CMS lines were sown on 28 October 2002 and seedlings were transplanted to the field, screenhouse and greenhouse on 10–11 December 2002. Additional plants of eleven of the entries were sown on November 11, and transplanted to the screenhouse and field on 27 and 31 December, respectively. Plants in all test sites were protected from insect –mediated cross pollination with 24-mesh net tunnels in the field, and plastic, glass and/or net closures in screenhouse and greenhouse. Randomized Complete Block Design (RCBD) was used in the field trials with two replications and 4 plants per plot. Plants were grown individually in 8" clay pots and arrayed randomly on benches in the greenhouse (six plants of each entry) and screenhouse (16 plants of each entry). Maximum and minimum temperatures of the three test environments were recorded daily during flowering.

Flowering behavior was observed weekly for four weeks, beginning 23 days after transplanting. The stability of sterility of the CMS lines was evaluated by noting the presence and viability of pollen during flowering with a 10x hand lens. Anther dehiscence and pollen released were scored as: Anther dehiscence: 0 = no anther dehiscence, 1 = partially anther dehiscence and 2 = anther fully dehiscence; Pollen release: 0 = no pollen release, 1 = some pollen released but adhering to anther, and 2 = pollen released freely. Fifteen anthers from a minimum of three flowers of each line from each site were collected randomly and squashed with 1% aceto-carmine stain to determine pollen viability. Pollen filled with stained cytoplasm was considered to be viable, while those lacking stained contents were classified as aborted and non-viable. The amount of viable pollen and also of aborted pollen produced were rated under 400X magnification on a 0 to 4 scale: 0 = no pollen, 1 = very few pollen, 2 = few pollen, 3 = some pollen and 4 = abundant pollen. Natural self-pollination and fruit setting was

measured. Green and red mature fruits were harvested in all locations on 19 March, 2003. Parthenocarpic fruits were discarded and only fruits with seed set were counted. Number of plants with fertile fruit, average number of fertile fruits per plant and average number of seeds per fruit were determined.

Results

The average temperature from transplanting through flowering ranged from 23.8°C to 14.3°C, 27.1°C to 14.3°C, and 28.2°C to 15.6°C for field, screenhouse, and greenhouse respectively. Temperatures in all environments fluctuated similarly due to weather conditions, although maximum temperature was typically 2-5°C higher in the screenhouse, and 5-8°C higher in the greenhouse than in the field. Minimum temperatures in all three settings were very similar, and ranged from 10-20°C through the flowering period, but generally ranged from10-15°C. Because of similarity of the temperature conditions and of results across the trial locations, average behavior of the entries over all three locations is reported here. Summary results are presented in table 2.

A strong association was found between the presence of viable pollen and large amounts of aborted pollen. Insignificant number of viable pollen was associated with low level (level 0, 1 and 2) of aborted pollen. Varying degrees of partial anther dehiscence were observed in all lines; neither full dehiscence nor complete non-dehiscence of anthers was observed. The amount of pollen released was generally associated with the combined total number of viable and aborted pollen grains. No pollen release was noted in cases where low levels of pollen were produced. Some pollen release was found in anthers producing significant viable and aborted pollen production or abundant aborted pollen plus little viable pollen. Freely released pollen occurred only in anthers producing large amounts of both viable and aborted pollen.

The relative amount of viable pollen produced was used to classify the stability of CMS lines (Table 2). CCA4757 and CCA4759 were classified as highly stable, as no significant quantities of viable pollen were recorded in four pollen-staining tests across three locations. PBC646, CCA4758, CCA4917, CCA5279, CCA5281, CCA5274, CCA5275 and CCA5276 were considered unstable lines, in that high levels of viable pollen were produced consistently throughout the experimental period. The remaining 5 lines displayed intermediate levels of viable pollen production.

Lines were again characterized on the basis of fruit and seed set (Table 2). Three lines, including the two highly stable lines CCA4757 and CCA4759, set no fruits with seeds in winter season at AVRDC. In five lines displaying intermediate levels of viable pollen production, selfed seed set was found on 5 to 10% of the plants examined. Of the eight lines that consistently produced large quantities of viable pollen, 5 lines (PBC 646, CCA 4917, CCA 5281, CCA 5275 and CCA 5276) produced seed on high percentages of plants, ranging from 38% up to 98%. The remaining three lines CCA 4758, CCA 5279 and CCA 5274 produced fruit with seed on only 2% to 6% of plants, and all of these were plants grown in the field, the coolest of the test sites. Overall, more CMS lines displayed a breakdown of sterility in field than in the screenhouse or the greenhouse. 10, 7, and 7 lines were recorded to set fruit with seed in the field, screenhouse and greenhouse, respectively. No clear trend was found among the entries in the proportion of selfed fruit set or average seed per fertile fruit over locations; e.g. two lines (CCA5271 and CCA5271) only produced spontaneously selfed seed in the greenhouse, while three other lines (CCA4758, CCA5279, and CCA5274) only set seed in the field, and one (PBC646) only set seed in the screenhouse. One line (CCA4916) performed in line with the relative maximum temperatures in the three environments. Abundant aborted and some viable pollen was found in the field, while only low levels of both aborted and viable pollen were produced in the screenhouse; and only rare viable pollen was found in greenhouse. Average aborted pollen scores were 3.25, 2.0, and 1.25, and average viable pollen scores were 1.75, 1.25, and 0.75 in the field, screenhouse, and greenhouse, respectively. Field grown plants produced more than three times as many selfed seed, on average, than did plants in the screenhouse, and no selfed seed was found in greenhouse grown plants. This line may prove useful in further studies of the sterility/reversal process.

Discussion

It should be noted that fruit and seed set in even the most reversible entries was a relatively small fraction of the spontaneous self pollination displayed in their maintainer (B-line) counterparts grown at the same time. Similarly, winter-grown CMS sterile anthers never produced as great a volume of pollen as their isogenic maintainer lines, and dehiscence was never complete, even in those lines in which sterility reversal was the greatest. The breakdown of sterility under low temperatures cannot be considered to be equivalent to a full restoration of fertility.

The fruit setting results were generally comparable with the pollen staining results: stable lines lacking viable pollen failed to set fruits with seeds; intermediate to high levels of viable pollen production elevated the frequency of self-pollinated fruits. Over the 15 lines tested in this study, highly significant correlations were found between the several pollen parameter scores and the practical output of the percentage of plants producing selfed seed. However, if the six lines in which more than ten percent of the plants set seed are excluded, the correlations became non-significant. Some lines displaying low pollen production ratings nevertheless successfully produced fruit with substantial numbers of seed (e.g. CCA 4758, CCA 5274). Careful examination of anthers at flowering may eliminate the majority of individuals with unstable sterility, but further confirmation of the absence of selfed seed production is needed.

The results highlight the importance of the initial CMS source in the stability of backcross progenies. Hot pepper CMS lines derived from PBC644 showed a lower tendency for sterility to break down in cool temperature than those derived from PBC646. Since higher percentage of seed set and significant amounts of viable pollen were found consistently in PBC 646 and its derivatives, PBC 644 is judged to be a better source for CMS line development. All lines tracing their CMS source to PBC646 displayed higher amounts of pollen, both viable and aborted, than any of the lines derived from the PBC644 source, except those in a sweet pepper background.

The role of the maintainer/recurrent parent genotype in developing stable CMS lines is also emphasized. CCA 4757 and CCA 4759 showed higher stability than the original CMS source PBC 644 and other lines derived from it; aborted and viable pollen were rarely noted; and no selfed seed was produced. Sterility modifier gene(s) insensitive to cool temperature may be present in the B-lines PBC 380 (Tit Paris), and PBC 483 (Arunalu), and may have contributed to enhancing stability. These modifier genes appear to be absent in the sweet pepper tested, since all three sweet pepper CMS lines tested showed great instability in this test. The use of CCA 4759 as the CMS source with new recurrent parents has proven useful, although the new series of recurrent parents are not displaying the same high levels of stability as PBC 380 or PBC 483. CCA 4757 could also serve as a good source of stable CMS sterility.

Conclusion

Compromised pollen sterility was found in most of AVRDC's CMS lines evaluated under cool winter conditions. CCA 4757 and CCA 4759 were found to be highly stable in that little viable pollen and no fruit with seed set were recorded. Modifiers of stability vary among recurrent maintainer lines, and some cytoplasm sources may be more stable than others. Screening of CMS lines in winter season is recommended for breeding highly stable CMS lines. While examination of anthers for evidence of sterility can narrow the number of candidate lines evaluated, it is still necessary to confirm the absence of spontaneous self pollinated seed set. Stability should be confirmed over two or more winter seasons before committing to large-scale hybrid seed production.

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Table 1. AVRDC CMS lines evaluated for male sterility stability.				
Code	**Pedigree by name**	**CMS Source**	**Description**	**Hot / Sweet**
PBC 646	Suwon cms (restricted distribution)	–	Parental Lines	Hot
PBC 644	Seungchon cms (restricted distribution.)	–	Parental Lines	Hot
CCA 4759	Seungchon(cms)/7*Arunalu	PBC 644	AVRDC CMS Lines	Hot
CCA 4757	Seungchon(cms)/7*Tit-Paris	PBC 644	AVRDC CMS Lines	Hot
CCA 4758	Seungchon(cms)/2*PBC385//5*(Saegochu/5*PBC385)	PBC 644	AVRDC CMS Lines	Hot
CCA 4916	Seungchon(cms)/6*Kunja	PBC 644	AVRDC CMS Lines	Hot
CCA 4917	Suwon(cms)/7*PBC292	PBC 646	AVRDC CMS Lines	Hot
CCA5279	Suwon(cms)/7*NLD-1seln	PBC 646	AVRDC CMS Lines	Hot
CCA5281	Suwon(cms)/6*Cipanas	PBC 646	AVRDC CMS Lines	Hot
CCA5271	Arunalu-A/4*Mr.Lee-No.3 seln	PBC 644	BC3F1	Hot
CCA5272	Arunalu-A/4*PBC308	PBC 644	BC3F1	Hot
CCA5273	Arunalu-A/4*Mito-Lee seln	PBC 644	BC3F1	Hot
CCA5274	Arunalu-A//4*HDA120/MI-Gold	PBC 644	BC3F1	Sweet
CCA5275	Arunalu-A/4*PBC84 seln	PBC 644	BC3F1	Sweet
CCA5276	Arunalu-A//4*BlueStar/ECW-30R	PBC 644	BC3F1	Sweet

Table 2. Fruit set/ Seed set results

	Average across Three Evaluation Sites										Fertile B-line	
Code	pollen staining result[1]	Aborted pollen score[2]	Viable pollen score[3]	Pollen Release Score[4]	Average Anther Dehiscence Score[5]	Number of readings	% of plants setting fruit	plants setting fruit/ total	Average fruits set/ plant	Average seeds set/ fruit	# of fruits set/ plant[6]	# of seeds set/ fruit[7]
PBC 646	U	2,8	2,7	0,6	1,0	11	62%	28/45	5,2	13	50	50
PBC 644	M	1,4	0,5	0,0	1,0	8	7%	3/42	1,7	5	60	50
CCA 4759	S	1,2	1,0	0,0	0,5	6	0%	0/50			45	40
CCA 4757	S	1,5	0,3	0,0	1,0	8	0%	0/49			50	90
CCA 4758	U	2,3	1,9	0,3	1,0	7	2%	1/50	1,0	30	140	30
CCA 4916	M	2,2	1,3	0,3	1,0	12	10%	5/50	1,6	14	52	60
CCA 4917	U	3,8	3,9	1,6	1,1	10	97%	47/48	7,1	34	30	100
CCA 5279	U	3,8	2,7	0,8	1,0	10	5%	1/22	1,0	4	15	30
CCA 5281	U	3,7	3,6	1,2	1,0	10	38%	19/50	2,3	28	75	70
CCA 5271	M	2,2	1,0	0,4	1,0	5	5%	1/22	1,0	14	35	50
CCA 5272	M	1,9	1,1	0,1	1,0	8	5%	1/22	1,0	6	25	50
CCA 5273	M	1,6	0,8	0,0	1,0	5	0%	0/13			15	30
CCA 5274	U	3,3	3,2	0,5	1,0	10	6%	3/50	1,7	49	5	150
CCA 5275	U	4,0	4,0	1,7	1,0	6	50%	24/48	5,0	59	8	150
CCA 5276	U	3,5	3,4	1,0	1,0	11	48%	24/50	4,2	59	3	--

[1]pollen staining result: S = highly stable, no significant number of viable pollen recorded; M = moderate levels of viable pollen production; U = unstable, high level of viable pollen expressed

[2,3]Aborted pollen score, Viable pollen score: 0=none; 1=very few pollen; 2=few pollen; 3= some pollen; 4= abundant pollen.

[4]Pollen release score: 0=no pollen released; 1=some released, but adhering to anther; 3=pollen released freely.

[5]Anther dehiscence score: 0=none; 1=partial dehiscence; 2=full anther dehiscence.

[6,7]Fruit set/plant, seed set per fruit: average of two fertile B-line plants grown in screenhouse; seed number rounded to nearest 10

'--' =no record

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IMPLICATION OF THE CAMBIAL TISSUE IN THE ESSENTIAL CALLUS FORMATION ON HOT PEPPER (*CAPSICUM ANNUUM* L.) PETIOLE EXPLANTS CULTIVATED *IN VITRO*

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1. Introduction

In the past years, there have been several reports on pepper (*Capsicum annuum* L.) plant regeneration *via* adventitious shoot organogenesis (Agrawal et *al.*, 1989; Ezura et *al.*, 1993; Szasz et *al.*, 1995; Deepu, 2002) or somatic embroygenesis (Binzel et *al.*, 1996). The most successful results were obtained using young explants, cotyledons and hypocotyls excised from *in vitro* seedlings (Szasz et *al.*, 1995; Deepu, 2002), although shoot elongation has repeatedly been found as a major obstacle in obtaining normal pepper plants (Steinitz et *al.*, 1999). Shoot-buds were regenerated directly with little or no intervention of callus, which is not capable of *de novo* shoot-bud regeneration (Agrawal et *al.*, 1989; Kintzios et *al.*, 1996). Culture experiments with mature pepper tissues were rarely reported (Kintzios et *al.*, 1996).

The aim of the present work is to evaluate the competence of mature petioles for callus formation and to identify tissues implicated in callus initiation in a Tunisian hot pepper cultivar.

2. Material and methods

Plant material

One hot pepper (*Capsicum annuum* L.) cultivar 'Baklouti' was used as experimental material. 'Baklouti' is a local selected variety from I.N.R.A.T (National Institute of Agronomic Research of Tunisia)

Mother plants were grown in glasshouse for 7 months (January- July) under uncontrolled environment.

Petioles used as explant sources were taken from the last sixth ramifications.

Culture conditions

Petioles were surface disinfected in 4% calcium hypochloride solution for 15 min, washed twice in sterile water, fragmented transversally into small pieces of 2 to 3 mm each and inoculated vertically, proximal side in contact with the culture medium.

Culture was established on Murashige & Skoog (1962) basal medium supplemented with 5 µM 2,4-D and 5 µM BA. The medium was adjusted to pH 5.8, autoclaved at 120° C for 20 min and poured into polystyrene (20 x 90 mm) Petri dishes. Each dish containing 35 ml of culture medium received fragments of the same petiole.

For each hormone level, the experiment was repeated 4 times.

Cultures were subsequently incubated in a growth chamber, in continuous darkness at a temperature of 25° C ± 2° C.

Histological study

To identify cell tissues responsible of the callus initiation, transversal sections were established on petioles collected at the same developmental stages than those used as explant donors.

Petioles fixed in ethanol 70% were cut by hand into transversal 20µm sections that were immersed in sodium hypochloride (12%) for 15 min. In this detergent, cell content is removed, but the cell wall remains intact. After several washings in distilled water, sections were immersed in diluted acetic acid (acetic acid: distilled water, 1:1 v/v) for 5 min and stained with a mixed iodine green-carmine solution for 7 to 10 min. In the presence of Carmine 40, pecto-cellulose becomes pink and in presence of iodine green, phenolic compounds (suberine, lignin and cutine) become green.

Coloured sections were then mounted in glycerine and observed under an optic microscope 'Leika DMLB'.

3. Results and discussions

Seven to ten days after inoculation on culture medium, callus induction started on the upper side of nearly 100% of petiole fragments (Fig. 1). Callus proliferation progressed rapidly to cover the whole explant and reached 1 to 2 cm after 20 to 25 days. No differences were clearly observed according to hormone level.

Petiole anatomy before inoculation is shown in figure 2 and more details on the different cell layers identity are given by figure 2b. Comparison between figure 1 and figure 2b indicates that the first cell proliferations implicated in callus formation essentially occur in cambium tissue. Some other cellular regions such as those situated on the petiole left extremity and having the pink colour of cambial cells seem to be as prolific as cambium. A secondary less important initiation takes place on epidermal cells.

According to Buvat (1989), cambium is constituted of secondary meristematic cells and presents therefore a high mitotic activity. Besides, the endogenous content of growth substances (auxins and cytokinins) is known to be negligible in superficial and medullar tissues as compared to cambial- derived tissue (Tran Thanh Van, 1980). The role of those substances in cell division regulation is very important (Boxus et *al.*, 1995).

Origin of callus and mainly of adventitious neoformations from *in vitro* cultivated tissues was studied by several authors. According to Tran Thanh Van (1980), fragments composed of orderly patterned tissues of diverse nature (epidermal and subepidermal, collenchymatous, vascular, cambial and medullar) always exhibit *de novo* bud formation only in superficial tissues (epidermal and subepidermal) and root formation in inner ones that derive from cambial tissue. The other neighboring tissues remain morphologically "silent" and may reveal some known or even unexpected morphogenetic potentials once excised from the fragment and cultured separately or reassociated in a different order than that naturally existing in the fragment. The antagonist effect of two neighboring tissues on each other suggests that "cell contact" may be an important factor in morphogenesis regulation.

In *in vitro* cultivated *Saintpaulia ionontha*, Rao (1977) noted that in petioles, buds developed exogenously from dedifferentiated epidermal and cortical tissues. In lamina, buds developed exogenously from dedifferentiated epidermal tissues or endogenously from callus tissues that originated from epidermis and mesophyll cell layers. The quantity of formed callus depended on the concentration of NAA and other growth substances used. Using electron microscopy, Schizuka (1994) demonstrated that first cell divisions inducing shoot primordium from lamina explants are restricted to epidermal cells adjacent to basal cells of glandular hairs.

Jemmali (1994) showed that adventitious stipular buds directly arose from subepidermal cells on micropropagated strawberry especially in presence of high BAP concentration.

In *Quercus ilex*, parenchymatous cells particularly those situated around vascularisation proliferated and gave rise to callus that later differentiated into nodules and then into somatic embryos (Feraud-Keller and Espagnac, 1989).

In *Nicotinia tabacum*, epidermal and mesophyll cell proliferations gave rise to calluses that later developed into buds (Gupta et *al.*, 1966; cited by Rao, 1977).

In *Chrysenthemum cinerariaefolium*, Roest (1976) noticed that first cell divisions leading to root induction occurred in the interfascicular pericycle, 3 to 4 days after incubation. After induction, some other pericyclic cells adjacent to the inducing cells became meristematic and contributed to the root primordium formation. Cambial cells also contributed to the growing root primordium, because a connection developed between xylem tissues of the original explant and the xylem of the initiated root. The suitability of pericycle to initiate roots is explained by inequivalence between the ontogenetic and physiological status of different tissues. In fact, pericycle that ages more slowly than adjacent tissues is less differentiated and then is more suitable for a subsequent dedifferentiation and root regeneration.

4. Conclusion

Our investigations revealed the cambium potentialities to induce callus on mature petioles. The important callus formation from cambium may be exploited if plant regeneration will be possible from those materials. Then regenerated plantlets could be used in different breeding programs like somaclonal variation, genetic transformation, etc.

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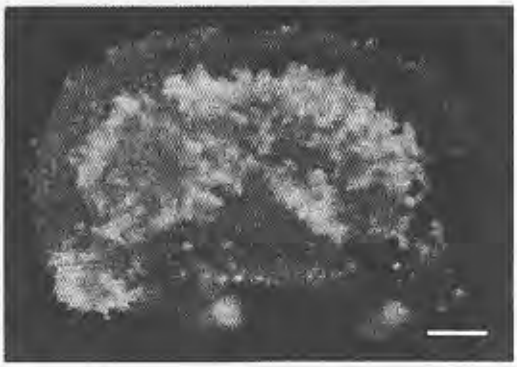

Figure 1. Cell proliferation on pepper (*Capsicum annuum* L. var Baklouti) petiole fragment after 8 days of incubation on culture medium, in darkness and at 25°C±2°C. Scale = 0.16 mm.

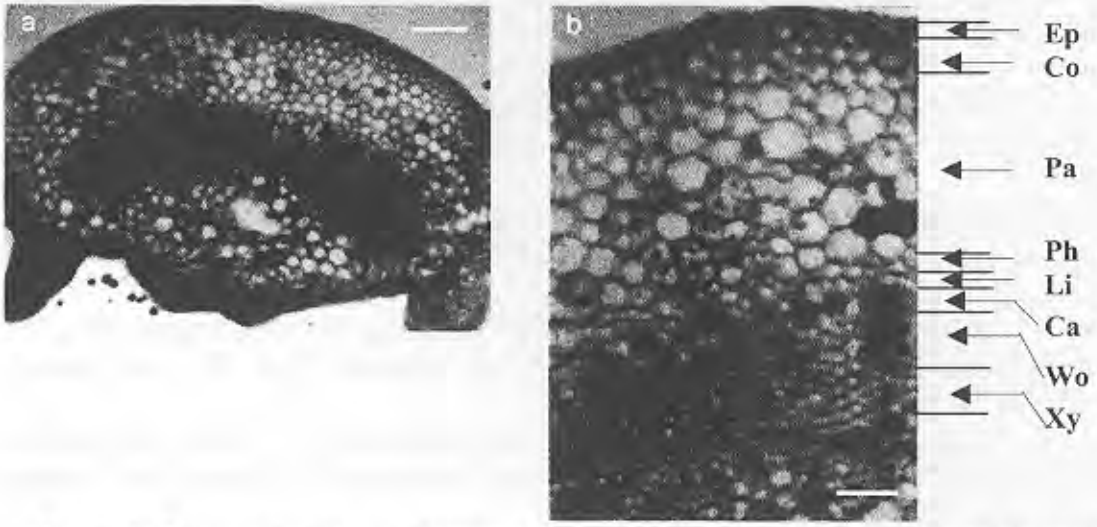

Figure 2. Transverse sections of pepper (*Capsicum annuum* L. var Baklouti) petiole explant before incubation

a: general view. Scale = 0.1mm.

b: detailed view showing the different cell layers. Ep: Epidemis; Co: Collenchyma; Pa: Parenchyma ; Ph: Phloem; Li: Liber; Ca : Cambium; Wo: Wood; Xy: xylem. Scale= 0.04 mm

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MULTIPLE SHOOT REGENERATION AND INDIRECT ORGANOGENESIS IN CHILLI PEPPER *(Capsicum annuum L)* .

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Abstract:

Repeatable protocols for rapid multiplication of a popular cultivar of *Capsicum annuum* L. cv. 'jwalasakhi' have been established through shoot multiplication and *de novo* organogenesis. Shoot tips cultured on Murashige and Skoog's (MS 1962) medium supplemented with 1-4 mg/l BA alone or in combination with 1mg/l 1AA/1BA/Kn induced multiple shoots. Maximum shoot multiplication was recorded in MS medium (MS 1962) supplemented with 4 mg/l BA along with 2mg/l Kn. Shoot buds sprouted directly from hypocotyl and cotyledon segments on MS medium containing high concentration of BA alone or in combination with 1AA/1BA or BA along with GA3. Callus initiated from cotyledonary leaf segments in a 2 mg/l NAA containing medium upon subcultured to a 3 mg/l BA and 1 mg/l GA3 enriched medium produced 4-6 shoot buds. Shoots developed were rooted in MS medium containing 1mg/l 1BA were hardened and successfully established in natural soil.

Introduction

Capsicum annuum L. commonly known as chilli or chilli pepper belonging to the family *Solanaceae* is cultivated as one of the important spice crop all over the world. Chilli besides imparting pungency and red colour to the dishes is a rich source of Vitamin A,C and E and assists digestion.Peculiar pungency of red pepper is essential for the wide spread use as condiments in highly spicy dishes especially in curries and in beverages. Early studies of acute and chronic pharmacological actions of capsaicin revealed a wide and interesting profile of biological activities(Guha *et al.*,1999).Chillies are also used as herbal medicines for treatment of systems ranging from itch and pain to constipation.

Although *in vitro* plant generation through direct adventitious bud formation from tissue cultures of red pepper were reported (Gunay and Rao, 1978, Fari and Czako, 1981, Phillips and Hubstenberger 1985; Agarwal et al; 1989, Sripichitt et al , 1989,Valera-Montero and Ochoa-Alejo 1992, Arroyo and Revilla, 1991, Ebida Aly and Hu, 1993, Christopher and Rajam 1996) there is lack of information on efficient plant regeneration from callus. The present paper describes the morphogenetic potentials of different explants and callus cultures of an important cultivar of *Capsicum annuum*.

Materials and methods

Seeds of *Capsicum annuum* L. cv. Jwalasakhi procured from Agricultural College, Trivandrum, Kerala were used for the study.The seeds were washed thoroughly for 2-3 hours in running tap water and later in a 0.1% aqueous labolene (a natural detergent, Qualigens, India.) for 10 min. The seeds were then surface disinfected with 0.1% w/v mercuric chloride solution for 5 min and after washing 3-4 times with sterile distilled water, they were inoculated in a basal Murashige and Skoog's medium containing 2% sucrose and gelled with 0.8% (w/v)agar. The pH of the media was adjusted to 5.8 and autoclaved at 121^{0}C under 15lbs pressure for15 min.

MS medium supplemented with 0.4-2mg/l 2,4– dichlorophenoxyacetic acid (2,4–D), 0.6-6mg/l indole acetic acid (IAA), 0.6-6 mg/l indole butyric acid (1BA), 0.4-6 mg/l naphthalene acetic acid (NAA), O.6-4 mg/l gibberellic acid (GA3), 0.4-6 mg/l kinetin (Kn,) and 0.4-6 mg/l benzyladenine (BA) was used for shoot multiplication, direct regeneration, callus regeneration and somatic embryogeneis. Hypocotyl, cotyledon and shoot tips from 15 days old seedlings were used as explants. The cultures were incubated in a sterile culture room maintained at 25± 1 °C on a 12 h photoperiod at a luminant exposure of 3000 lux provided by cool, white, fluorescent tubes.

The experiments were repeated thrice and subculturing was done on every 28 days. The shoots were transferred to MS medium with 0.1-1mg/l 1BA for rooting .

The plantlets recovered from agar were placed on filter paper bridges and liquid sugar free MS basal medium for 15 days before transfer to sterile vermiculite. After acclimatizing the plantlets in the controlled conditions, they were transferred to pots containing garden soil and sand mixture (1:3)

Results and discussion

Shoot cuttings, treated with different hormonal concentrations of BA/Kn individually or in combination with auxins (IAA/1BA, exhibited varied responses, mostly in terms of number of shoots formed and their elongation.

Presence of 4 mg/l BA in the medium favoured shoot sprouting (Fig.1A) from the explanted shoot tips. Addition of different levels of Kn to medium with the optimal levels of BA (4mg/l) enhanced the number of shoots. BA(4mg/l) in combination with Kn(2mg/l) yielded maximum number of shoots. About 63 shoots were recovered within 85 days after three subcultures. Number of shoots on medium supplemented with Kn was lesser as compared to BA(Table 1). The developed shoots attained more than 4cm height within 40days.

Shoot buds were induced directly from the hypocotyl as well as cotyledonary explants on MS medium supplemented with 2-5 mg/l BA alone or in combination with 0.5–1mg/l 1AA or 1BA.These combinations were earlier reported in different varietiesof this plant.(Gunay and Rao, 1978, Fari and Czako, 1981,Ebida Aly IA & Hu CY 1993). Cotyledonary explants developed larger number of shoot buds (20-25 nos.) compared to that of hypocotyls (8-10)(fig.1). There was slight callussing from the cut regions of the explant in all the combinations used. BA and NAA combinations tried were not suitable for shoot bud induction. However, rooting and callus formation from the explant were characteristic. A combination of 1 mg/l GA3 and 3 mg/l BA also induced direct shoot formation from cotyledonary segment which is not reported in other varieties of Capsicum(Fig 1 B,C,D). This is similar to the report in *Naragamia alata* where GA3 had acted synergistically with BA in shoot bud initiation (John etal., 1997). Shoot buds also sprouted *de novo* from hypocotyl and cotyledonary segments cultured on MS medium supplemented with BA alone . 4 mg/l BA was found to be most effective. Kinetin in place of BA at all concentration did not evoke any response which is in contrast to the earlier report in *C. annuum* cvs. Pico and Piquitto (Arroyo and Revilla, 1991).

Callus was initiated from cotyledonary leaf hypocotyl and root segments using MS medium with varying concentrations of auxins and cytokinis. Additon of 0-5 1mg/l NAA and IAA induced callus as well as roots 2,4 D, usually produced friable, actively growing callus without roots, but 2,4 D in the primary culture inhibited the shoot formation even after subculturing to different hormones in combinations. The friable fast proliferating callus, initiated from cotyledonary segments, when grown as agitated suspension cultures containing 2 mg/l 2,4 D and 1mg/l KN, developed into uniform, spherical or heart shaped structures. These embryogenic structures grown for prolonged period in 2,4-D containing medium recallused without any further development(Fig.1F). Organogenesis was obtained from the callus initiated in 4 mg/l NAA and subcultured to 3 mg/l BA and 1mg/l GA3, but the number of shoot buds produced was less (4-6) compared to the direct shoot bud formation(Fig.1E).This is a new report where shoots were induced from callus in this medium *ie.* MS+1mg/lGA_3+3mg/lBA. This is also in accordance with the report in *Solanum tubersoum* (Webb et al., 1983) where callus regeneration was obtained in a medium with 3 mg/l BA and 1mg/l GA3.

The elongated shoot buds developed through various protocols transferred to MS medium containing 1mg/l IBA developed profuse branched roots within 7-10 days. After conditioning in sucrose free MS basal medium on filter paper bridges for another 10 days, the plantlets were transferred to plastic pots (Fig.1)containing autoclaved vermiculite and grown under high humidity and illumination and subsequently to potting mixture and grown under controlled condition and later transferred to field. The plantlets transferred this way showed luxurient growth under field conditions with about 90% survival.

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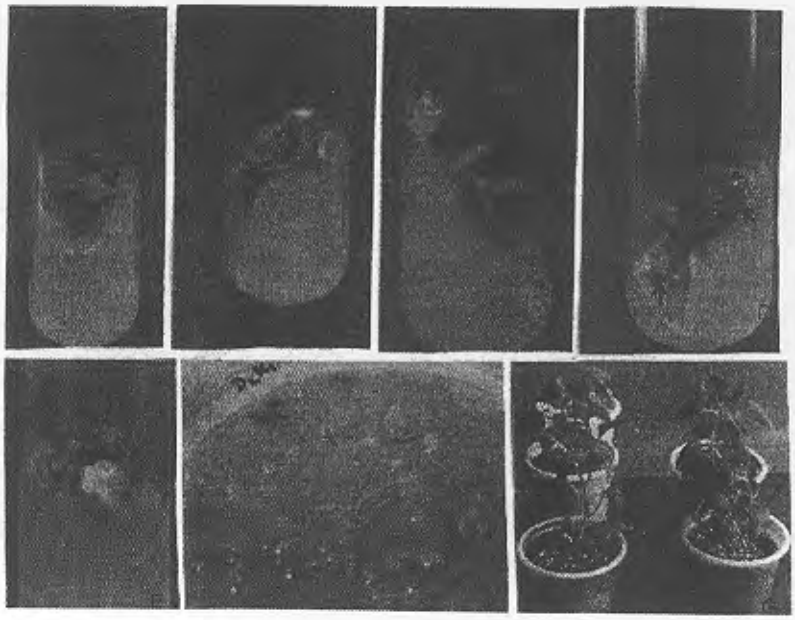
Table 1:-Regeneration response of different explants of Capsicum annuumL.

Explant	HORMONES USED mg/l IAA	GA3	BA	KN	Response	Number of Shoots regenerated ± SE	Rate of survival (%)
	1		2			4.5	85
	1		4			15.8	89
Shoot tip	1		6		Shoot	4.2	92
	2		2		multiplication	4.1	86
			2	3		15.9	88
			3	2		16.2	86
			4	2		63.9	90
			2			12.5	86
			4			26.2	88
			6			11.8	86
Coty.leaf		1	2		Direct	6.5	90
		1	3		regeneration	10.3	90
		1	4			20.17	88
		2	4			25.54	90
		2	2			7.5	88
		1	3			17.23	91
		1	1			1.03	93
Callus		2	2		Callus	2.6	92
		1	3		regeneration	7.32	93
		1	5			3.2	90

* For shoot multiplication data recorded after two passages
**For direct and callus regeneration data recorded after one month

Fig.1- Morphogenetic responses of Capsicum annuum L.



A - Shoot multiplication **D,E- Callus regeneration** **B,C- Direct regeneration**
F- Embryogenic callus **G- Elongated plants**

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A viable protocol for direct regeneration of bell pepper (*Capsicum annuum* L.) cv. California Wonder

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Introduction

Capsicum, commonly called chilli, is the universal spice of India. he genus onsists of five cultivated species, of which commercially important are *C. annuum, C. frutescens* and *C. chinense*. Bell pepper belongs to *C. annuum* and is so called because of the characteristic shape of the fruit. The fruits are non-pungent when compared to red chilli and are used raw in salads or cooked into curries. It is also used as a dried vegetable in European and North African countries. Application of cell and molecular biology techniques to Capsicum for its genetic improvement by developing transgenic plants has been limited because of the lack of an efficient and reproducible regeneration system. A few reports are available on *in vitro* regeneration from cotyledon and hypocotyls explants (Arroyo and Revilla, 1991; Valera-Montero and Ochoa-Alejo, 1992 Ramage and Leung, 1996). These reports indicate formation of cabbage leaves which remain in rosette form and failure of shoot buds to elongate. Differential response of varieties is also prominent and protocol has to be developed for each variety. In this paper, we discuss the results of an attempt to develop a viable regeneration system in Capsicum variety California Wonder through tissue culture technique using hypocotyl segments as explant.

Materials and methods

Seeds of *C. annuum* cv. California Wonder obtained from Indian Agricultural Research Institute, Regional Station at Kulu Valley were surface sterilized with 0.1 percent mercuric chloride for one minute. Seeds were then thoroughly rinsed with sterile water, germinated on semi-solid Murashige and Skoog (MS) medium supplemented with 2% sucrose and incubated at 25 ± 2 ^{0}C under 2000 lux for 12h photoperiod.

Hypocotyl segments of approximately 1cm length were excised from 16-21day old seedlings were placed vertically, upside down on semi solid MS medium supplemented with cytokinin (benzyl adenine) and auxin (indole acetic acid) at various concentrations. Each treatment consisted of 54 replications. Cultures were maintained under the same conditions mentioned above. Adventitious buds formed were transferred to MS medium supplemented with 2 percent or 3 percent sucrose for shoot elongation. Elongated shoots were removed, given pulse treatment with 1000µg/l. IBA and inoculated on MS semi solid medium containing sucrose and /or activated charcoal. Rooted plants were carefully taken out of tubes, adhering agar particles removed by washing in tap water. These were planted in pots containing sterile sand and kept in mist chamber for 15 days for hardening. Hardened plants were then planted in bigger pots and transferred to glass house.

Results and discussion

Plant regeneration from cotyledon and hypocotyl segments has been attempted by several workers. Hypocotyl segments generally produced roots and only the acropetal part differentiated shoot buds (Ramage & Leung, 1996). Shoot buds grew into rosette and did not elongate. Valera-Montero and Ochoa-Alejo reported adventitious bud formation when rooted hypocotyls were placed upside down in medium.

In the present study, morphogenic response of hypocotyl segments placed upside down in MS medium with different combinations of IAA and BA was studied. Initiation of regeneration was observed 7 days after inoculation. MS medium supplemented with 0.3mg/ l IAA and 5mg BA/ l or 0.2mg/l IAA and 3.5 mg/l BA recorded highest percentage of organogenesis (Table 1). Number of shoot buds developed per hypocotyl segment was also maximum in the above treatments (Plate1). In the other treatments, there was either no response or very little regeneration along with callusing. The number of shoot buds developed from each explant ranged from 7.5 to 16.5. previous studies with hypocotyl segments of *C. annuum* cv. Chile de agua have established requirement of both cytokinin and auxin to induce development of adventitious buds (Valera-Montero and Ochoa-Alejo, 1992). In their protocol, adventitious buds were placed on the medium as a clump. Our protocol differs from this in that, the buds were separated into four or five pieces, each containing three to four buds. From each clump, one or two plantlets were obtained.

For elongation of shoots, MS medium containing 2 or 3 percent sucrose and 0.025 percent activated charcoal was found to be the best. Addition of GA or 2,4-D did not improve elongation of shoot. However, from each cluster of shoot buds, only one or two showed elongation. Other buds grew into rosettes with numerous well-developed leaves, and failed to elongate (Plate 2). This difficulty was overcome by excising the elongated shoot which led to further elongation of other buds.

Elongated shoots were easily rooted by placing them in MS medium containing 2 or 3 percent sucrose and / or activated charcoal. Pulse treatment with IBA at 1000ppm enhanced early rooting (4 days) when compared to the untreated ones (9.5 days) (data not shown). Presence of activated charcoal induced more number of roots per plantlet (Table 3). The root system was properly established in another 10 days (Plate 3). Rooted plants, after hardening in the mist chamber, were transferred to pots and maintained in glass house (Plate 4). Thirty such plants are now being maintained.

In conclusion, we have developed a viable protocol for direct regeneration of bell pepper from hypocotyl segments, which can produce five plantlets from one explant. This protocol is now being tested in our lab for genetic both direct and indirect transformation for genetic improvement of this economically important vegetable.

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Table 1. Regeneration of hypocotyl segments of bell pepper in different media combinations

Sl. No.	Media combinations	Regeneration (%)	Response of hypocotyl	No. of buds per hypocotyl
1.	MS+0.5 mg/l IAA+2.5 mg/l BA	nil	N	Nil
2.	MS+0.5 mg/l IAA+5 mg/l BA	33	O,C	12.5
3.	MS+0.5 mg/l IAA +7 mg/l BA	nil	N	Nil
4.	MS+0.5 mg/l IAA+10 mg/l BA	nil	N	Nil
5.	MS+0.7 mg/l IAA +2.5 mg/l BA	nil	N	Nil
6.	MS+0.7 mg/l IAA +5 mg/l BA	66	O,C	14.5
7.	MS+0.7 mg/l IAA+ 7 mg/l BA	20	O,C	8.5
8.	MS+0.7 mg/l IAA +10 mg/l BA	nil	N	Nil
9.	MS+1 mg/l IAA+ 2.5 mg/l BA	nil	N	Nil
10.	MS+1 mg/lAA + 5 mg/l BA	nil	N	Nil
11.	MS+1 mg/l IAA+7 mg/l BA	nil	N	Nil
12.	MS+1 mg/l IAA+10 mg/l BA	25	O,C	7.5
13.	MS+0.3 mg/l IAA+5 mg/l BA	100	O	15.5
14.	MS+0.2 mg/l IAA+3.5 mg/l BA	100	O	16.5

O:Organogenesis C: Callusing N: No response

Table 2. Elongation of regenerated buds as affected by growth hormones

Sl. No.	Media combination	Response
1.	MS solid +(3% sucrose)	shoot elongation & rooting
2.	MS solid + (2% sucrose)	shoot elongation & rooting
3.	MS solid +0.025% AC*	shoot elongation & rooting
4.	MS solid +0.025% AC* (2% sucrose)	shoot elongation & rooting
5.	MS+0.7 IAA mg/l	leaf proliferation
6.	MS+1 IAA mg/l	leaf proliferation
7.	MS+2 mg/l IBA	rooting alone
8.	MS+2mg/l GA	leaves leathery and brown
9.	MS+5mg/l GA	leaves leathery and brown
10.	MS+8mg/l GA	leaves leathery and brown
11.	MS+10mg/l GA	leaves leathery and brown
12.	MS+1 mg/lkin+0.5mg/l 2,4-D	leaf proliferation alone

* Activated charcoal

Table 3. Effect of sucrose and activated charcoal on rooting of elongated buds in bell pepper

Sl. No.	Media composition	Rooting (%)	No. of roots/ plant
1.	MS+3%sucrose	100	14.50
2.	MS+2%sucrose	100	14.75
3.	MS+3%sucrose+0.025% activated charcoal	100	21.50
4.	MS+2%sucrose+0.025% activated charcoal	100	21.80

Plate 1. Regeneration from hypocotyls of Capsicum annuum cv. California Wonder

Plate 2. Shoot elongation of regenerants

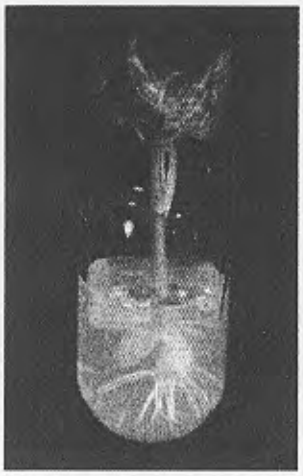

Plate 3. Rooted plantlet

Plate 4. Hardened plant outs

In vitro regeneration in *Capsicum annuum*

Capsicum and Eggplant Newsletter 23 (2004): 101-104.

ANTHER CULTURE OF PEPPER (*Capsicum annuum L.*): THE EFFECT OF NUTRIENT MEDIA

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Introduction: The development of valuable haploid plants useful in genetics as well as in practical selection is purpose of the *in vitro* cultivation of anthers. The first data for obtained haploids via anther culture of pepper (*Capsicum annuum L.*) were published by Wang *et al.* (1973), George *et* Narayanaswamy (1973) and Kuo *et al.* (1973). The successful embryoid induction and microspore regeneration depends on a number of factors: stage of microspore development, low temperature pretreatment (Sibi *et al.*, 1979), elevated temperature treatments (Dumas de Vaulx *et al.*, 1981), genotype and donor plant age (Morrison *et al.*, 1986; Gomez & Chambonnet, 1992; Kristiansen & Andersen, 1993; Qin & Rotino, 1993; Ltifi & Wenzel, 1994; Mytiko *et al.*, 1995), culture medium (Sibi *et al.*, 1979; Vagera & Havranek, 1985; Pundeva *et al.*, 1990; Boyaci, 2001; Ellialtioglu *et al.*, 2001) etc.
The aim of the present study was to investigate *in vitro* response of anther culture of Bulgarian pepper lines, varieties and hybrids cultivated on different nutrient media.

Materials and methods: Donor plants of four lines (№№145, 146, 1312 and 1924), five varieties (Zlaten medal, Hebur, Stryama, Albena and Kourtovska kapiya) and two F1 hybrids (№1647 x №1969 and №1647 x №1962) developed in the Maritsa Vegetable Crops Research Institute-Plovdiv, were grown in greenhouse. Flower buds were collected at the late uninucleate microspore stage (Sibi et al., 1979). The excised anthers were cultivated on the following media:

1. Medium C + 2 mg/l kinetin + 0,1 mg/l 2,4-D (Dumas de Vaulx *et al.*, 1981);
2. Medium C (Dumas de Vaulx *et al.*, 1981), without growth regulators;
3. Medium C (Dumas de Vaulx *et al.*, 1981) + 0,01 mg/l kinetin and 2,4-D, respectively (Gyulai *et al.*, 2000);
4. Medium Cm + 2 mg/l kinetin and 2,4-D, resp. (Sibi *et al.*, 1979);
5. Medium Cm (Sibi *et al.*, 1979), without growth regulators;
6. Medium Cm (Sibi *et al.*,1979) + 0,01 mg/l kinetin and 2,4-D, resp.;
7. Medium MS (Murashige *et* Skoog, 1962), without growth regulators;
8. Medium MS (Murashige *et* Skoog, 1962) + 0,2 mg/l kinetin + 2 mg/l IAA;
9. Medium MS (Murashige *et* Skoog, 1962) + 2 mg/l NAA and BA, resp. (Park *et al.*, 1992);
10. Medium MS (Murashige *et* Skoog, 1962) + 0,1 mg/l kinetin + 0,004 mg/l 2,4-D (Matsubara *et al.*, 1998);

The incubation were according to Dumas de Vaulx *et al.* (1981).The frequency of anthers producing callus or direct embryoids from each genotype were recorded. The embryoids developed into microplants were presented in percentage both to the total number of anthers and to the number of obtained direct embryoids from the respective genotype.

Results and discussion: The responsive anthers from the studied genotypes reacted with callusogenesis without regeneration or with direct embryoid formation on the different tested media. There was considerable variation in the response of studied genotypes to different medium. Only in one case we registered explants with indirect organogenesis but without developed structures (medium 1). Direct embryoids developed in microplants were observed in three media (1,2,10).
The results of the effect of C media (1,2,3) are shown in Table 1. The highest embryogenic response were observed on medium 1 compared to media 2 and 3. In the same medium we observed regenerative structure formation via callus (var. Zlaten Medal) and direct embryoids developed into microplants (var. Stryama – 20% of embryos). Direct embryoid formation on medium 2 without growth regulators were observed in Stryama genotype only where 50% of embryos developed into regenerants. No embryos have been obtained from all genotypes on medium 3; there was callusogenesis only. The most of studied genotypes were unresponsive on media 2 and 3.

The results of the Cm media effect (4,5,6) are presented in Table 2. Embryogenic response were observed in medium 4 only in the most of studied genotypes (7 from the studied 10).
On one of the tested MS media (7,8,9,10) we observed the highest number of genotypes reacted with direct embryogenesis (medium 10) compared with 7, 8 and 9 media (Table 3). On the same medium we observed embryoids developed into microplants (line №145 – 33,34%).
In the media without growth regulators (2, 5, 7 – Table 1, 2 and 3) higher embryogenic response was observed on medium 7 (30% of tested genotypes) but without development to regenerants. No embryos have been obtained in medium 5. Direct embryo formation on medium 2 was shown only in Stryama genotype and 50% of embryoids develpoed to microplants. From this we can conclude that the lack and also the lower content of tested plant growth regulators (kinetin and 2,4-D) in the media don't provoke the direct embryogenesis but often influence positively callusogenesis.
From all the tested media (Tabl. 1, 2 and 3) the highest number of genotypes (72,7% of all tested) with direct embryo formation but without development into regenerants we registered on medium 4. Probably the higher auxin – cytokinin ratio influences positively on this process. The embryogenic response observed in media 1 and 10 (54,5% and 55,6% of all tested genotypes resp.) results in microplants formation (20% and 33,34% of embryoids, resp.). It is very probably the regeneration process in this case is in the result of suitable auxin – cytokinin ratio (lower auxin concentration : higher cytokinin concentration) in the media.
In all of the studied media and in almost all of the studied genotypes was registered comparatively low level of regenerative activity.The considerable variation in the response of different genotypes to different media suggest evident genotypic "preferences".

Conclusions:

- The *in vitro* response of studied pepper anther culture to a great extent depends on donor plant genotype, medium composition, supplements and growth regulators.
- The media C and MS with lower auxin concentration to the cytokinins are suitable for direct embryogenesis in anther culture of the most of the tested genotypes.

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Tab.1. Callusogenesis, embryogenesis and regeneration on variants of C media (in %).

media	1						2					3				
	reacted (%)			regenerants (%)			reacted (%)			regenerants (%)		reacted (%)			reacted (%)	
genotypes	total	direct embryoids	callus	indirect organogen.	to number of anthers	to direct embryoids	total	direct embryoids	callus	to number of anthers	to direct embryoids	total	direct embryoids	callus	to number of anthers	to direct embryoids
N 145	12,07	0	12,07	0	0	0	-	-	-	-	-	9,09	0	9,09	0	0
N 146	10,2	0	10,2	0	0	0	0	0	0	0	0	8,82	0	8,82	0	0
N 1312	1,28	1,28	0	0	0	0	2,78	0	2,78	0	0	-	-	-	-	-
N 1924	27,45	0	27,45	0	0	0	0	0	0	0	0	0	0	0	0	0
Zl. Medal	44,45	4,94	38,27	1,23	0	0	0	0	0	0	0	0	0	0	0	0
Hebur	21,15	7,69	13,46	0	0	0	2,44	0	2,44	0	0	0	0	0	0	0
Stryama	26,09	10,87	15,22	0	2,17	20	6,67	1,91	4,76	0,95	50	0	0	0	0	0
Albena	36,99	10,96	26,03	0	0	0	-	-	-	-	-	61,12	0	61,12	0	0
K. kapyja	9,76	0	9,76	0	0	0	-	-	-	-	-	0	0	0	0	0
F1 1647x1969	2,7	0,68	2,03	0	0	0	0	0	0	0	0	13,43	0	13,43	0	0
F1 1647x1962	15,18	0	15,18	0	0	0	-	-	-	-	-	0	0	0	0	0

Tab. 2. Callusogenesis, embryogenesis and regeneration on variants of Cm media (%).

media	4				5				6			
	reacted (%)			regenerants	reacted (%)			regenerants	reacted (%)			regenerants
genotypes	total	direct embryoids	callus	to direct embryo (%)	total	direct embryoids	callus	to direct embryo (%)	total	direct embryoids	callus	to number of embr.(%)
N 145	47,83	2,17	45,65	0	37,5	0	37,5	0	14,81	0	14,81	0
N 146	20,84	0	20,84	0	8,89	0	8,89	0	-	-	-	-
N 1312	14,55	1,82	12,73	0	-	-	-	-	11,76	0	11,76	0
N 1924	5,17	0	5,17	0	-	-	-	-	-	-	-	-
Zl. Medal	3,45	3,45	0	0	6,25	0	6,25	0	9,09	0	9,09	0
Hebur	10,35	3,45	6,9	0	-	-	-	-	-	-	-	-
Stryama	22,23	5,56	16,67	0	3,7	0	3,7	0	-	-	-	-
Albena	33,93	7,14	26,79	0	0	0	0	0	-	-	-	-
K. kapyja	0	0	0	0	-	-	-	-	-	-	-	-
F1 1647x1969	26,55	0,89	25,66	0	0	0	0	0	7,69	0	7,69	0
F1 1647x1962	19,28	4,82	14,46	0	0	0	0	0	11,32	0	11,32	0

Tab. 3. Callusogenesis, embryogenesis and regeneration on variants of MS media (%).

media	7				8				9				10				
	reacted (%)			regenerants	reacted (%)			regenerants	reacted (%)			regenerants	reacted (%)			regenerants (%)	
genotypes	total	direct embryoids	callus	to number of embr.(%)	total	direct embryoids	callus	to number of embr.(%)	total	direct embryoids	callus	to number of embr.(%)	total	direct embryoids	callus	to number of anthers	to number of embryoids
N 145	0	0	0	0	9,62	0	9,62	0	21,85	1,68	20,17	0	13,51	8,11	5,41	2,7	33,34
N 146	13,6	0	13,6	0	38,1	0	38,1	0	30,19	0	30,19	0	10,53	0	10,53	0	0
N 1312	0	0	0	0	5,56	0	5,56	0	10	0	10	0	7,69	7,69	0	0	0
N 1924	0	0	0	0	3,7	0	3,7	0	-	-	-	-	0	0	0	0	0
Zl.medal	-	-	-	-	12,3	0	12,28	0	-	-	-	-	18,57	5,71	12,86	0	0
Hebur	0	0	0	0	-	-	-	-	0	0	0	0	8,34	0	8,34	0	0
Stryama	5,26	0	5,26	0	22,2	0	22,23	0	16,67	0	16,67	0	10	4	6	0	0
Albena	6,67	1,12	5,56	0	6,67	0	6,67	0	38,71	9,68	29,03	0	-	-	-	-	-
K.kapyja	0	0	0	0	17,7	0	17,65	0	0	0	0	0	-	-	-	-	-
1647x1969	18,3	2,82	15,5	0	17	0	17,02	0	38,89	0	38,89	0	0	0	0	0	0
1647x1969	53,9	11,54	42,3	0	5,79	0,83	4,96	0	1,41	0	1,41	0	44,45	11,12	33,34	0	0

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APPLICATION OF ANTHER CULTURE AND MOLECULAR MARKERS TO A PEPPER BREEDING PROGRAM FOR DISEASES RESISTANCE.

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INTRODUCTION

Pepper (*Capsicum annuum* L.) is one of the most important vegetable crops in Spain. Virus diseases are among the main constraints of pepper production. In addition to viral diseases, *Phytophthora capsici* Leon. is the most serious fungal disease in temperate areas. Therefore, breeding pepper varieties with joint resistance to diverse pathogens is an objective of any selection programme.
At the present time several disease resistance sources in pepper are known. The *C. annuum* variety 'Serrano Criollo de Morelos-334 ('SCM-334') has high levels of resistance to *P. capsici* and Potato Virus Y (PVY, gene *Pvr4*), as well as to Tomato Mosaic Virus (ToMV, gene *L1*). Another well-known source of resistance to *P. capsici* is the *C. annuum* line 'PI-201234'. For years, our group has developed six lines with joint resistance to *P. capsici*, ToMV and PVY (pathotype 1-2), using as recurrent parent lines of the types 'Yolo Wonder' (YW) and 'Morrón'. Nevertheless, the breeding processes are long and expensive, reasons why the use of anther culture and molecular markers linked to resistance genes would facilitate them. Therefore, the objective of this work was to obtain from the six previously mentioned lines, several dihaploides lines (DH) to be used as hybrid parents resistant to the three above mentioned pathogens. In addition, the resistance to PVY-1-2 was evaluated by means of molecular markers related to the *Pvr4 locus*.

DISEASES SCREENING. OBTENTION AND STUDY OF DIHAPLOID LINES.

During the first year we worked with a number of plants between 12 and 342 by line (Table 1). First, the pepper plantlets were inoculated by irrigation with a *P. capsici* suspension holding 10^4 to 10^5 zoospores/ml. Among the six tested lines 'Nº 4' was the most susceptible to *P. capsici*, with only 42 % of resistant plants. This greater susceptibility could be attributed to the use of *P. capsici* susceptible lines as recurrent parents in the last backcrosses to develop 'line 4'.
Plants that survived to *P. capsici* inoculation were tested with a ToMV isolate. The most outstanding result was the low percentage (43 %) of ToMV resistant plants in 'line 6'. This line was the unique one in which ToMV susceptible recurrent parents were used in the backcross programme. Finally, the plants that surpassed the previous inoculations were inoculated with PVY 1-2 (isolate

P-22-88) and resistant and susceptible plants were found in the expected proportions according to their origin (Table 1). Once known the PVY-1-2 resistant and susceptible plants, we studied whether the gene *Pvr4* was present in homozygous or heterozygous condition in the resistant ones. For that purpose, its DNA was amplified, following the processes of extraction, quantification and DNA amplification as described by Arnedo-Andres *et al.* (2002), using the SCAR (Arnedo-Andres *et al.*, 2002) and CAPS (Caranta *et al.*, 1999) markers, linked to the *Pvr4* alleles for susceptibility and resistance, respectively. The most outstanding result was that the number of homozygous resistant plants detected, except for 'line 1', went far below to the expected 1/3 of them (Table 1).

TABLE 1. Resistance on six breeding lines after sucesive inoculation with *P.capsici*, ToMV and PVY-1-2, and number of PVY-1-2 resistant plants that amplified the marker $SCUBC19_{1423}$.

Line	N° of plants	*P. capsici* resistant plants (%)	ToMV resistant plants (%)	N° of PVY inoculated plants	N° of PVY resistant plants	$SCUBC19_{1423}$[1] (homozygous PVY resistant plants)
1	59	66	64	19	17	9
2	100	76	63	27	18	1
3	342	80	77	212	156	4
4	12	42	60	3	1	0
5	46	67	71	22	14	1
6	87	79	43	30	16	1

[1]Number of PVY-1-2 resistant plants that did not amplified with the marker $SCUBC19_{1423}$, and in conclusion should be the only homozygous resistant to PVY-1-2.

In order to verify the correct operation of these markers in these materials, they were confirmed in all the parents that had taken part in the breeding of the six lines. It could be established that the SCAR marker worked correctly (Figure 1) and contributed the correct information, while the CAPS markers did not have the behaviour expected when analysing some of the used parents and those divergences come up when analysing the breeding lines.

Figure 1: Results of amplification with $SCUBC19_{1423}$ marker on 24 PVY resistant plants from 'line 3'. Lane 1: 1 kb marker; Lanes 2-13, 15-22 and 24: *Pvr4* heterozygous resistant plants; Lanes 14 and 23: *Pvr4* homozygous resistant plants.

Plants resistant to the screenings with the three pathogens, were grown in a greenhouse sited in Almeria province to study plant and fruit traits and consequently to make a selection of the most interesting ones. Therefore, 33 plants were selected from lines 1, 2, 3 and 4 and 84 dihaploid lines (DH) were obtained from them. Classification of the DH lines into homozygous PVY-1-2 resistant and homozygous PVY-1-2 susceptible lines, was accomplished by means of the SCAR marker. The results showed that among the 84 DH lines, 25 were homozygous resistant and 54 susceptible ones. This result was not the expected one because the DH lines should have segregated at the rate 1:1.

DISCUSSION.

One of the reasons to explain the low number of homozygous PVY-1-2 resistant plants detected in the disease screenings (last column in Table 1), could be a negative linkage between resistance to PVY-1-2 and the resistance to the other two pathogens. Anyhow, the hypothesis of a linkage between the resistance to *P. capsici* and the susceptibility to PVY1-2 could be rejected because the percentage of plants susceptible to *P. capsici* in the homozygous PVY-1-2 resistant DH and homozygous PVY-1-2 susceptible DH lines, was not statistically significant, 23,7 % and 28,1 % respectively. Also based on the results of this work (data not shown), a negative relationship between ToMV and PVY-1-2 resistances was discarded as well. On the other hand, the present knowledge on the genetics of resistance to the three pathogens suggests no relationship between the genomic regions where the corresponding genes and QTLs has been located (Lefebvre *et al.*, 2002). Nevertheless, another explanation for the distortion should be the existence of *P. capsici* resistance associated QTLs not yet detected. In fact in 'SCM-334', where different levels of resistance to *P. capsici* and PVY has been observed (Guerrero and Laborde, 1980, Pasko *et al.*, 1992), when our group has selected for higher *P. capsici* resistance a higher percentage of PVY-1-2 susceptible plants, therefore lacking the gene Pvr^4, has been obtained (data not shown).

On the other hand, Lefebvre *et al.*, (1995) detected in crosses involving the parent SCM-334 that several genomic regions gave aberrant segregation ratios often favouring the agronomic parent, just as have been observed with the *locus Pvr4* in our case. According to our results that abnormal selection takes places during gametogenesis (last column in Table 1) and it could also take place during any of the different steps, included anther culture, to the production of DH lines, with the abnormal result of 25 PVY-1-2 resistant and 54 PVY-1-2 susceptible ones. Segregation distortion among anther-culture-derived plants has also been observed in other species. Very recently it has been reported in barley (Sayed *et al.*, 2002).

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NEW RESISTANCE TO PLANT VIRUSES IN PEPPER

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ABSTRACT

Virus diseases of pepper (*Capsicum* spp.) can be a major limiting production factor. Resistance to these viruses is at present the best available control method. We have tested over 250 open-pollinated *Capsicum* spp. for resistance to cucumber mosaic virus (CMV), pepper mottle virus (PepMV), potato virus Y (PVY), and tobacco etch virus (TEV) and found several previously unreported resistant pepper lines or cultivars.

Species of *Capsicum* (pepper) represent one of the most diverse commercially grown vegetables, varying greatly in pod shape, color, and pungency. Use of this high-value crop has increased more than 21% since 1994 with more than 3 million hectares grown worldwide (Chili Institute, Las Cruzes, NM). Plant virus diseases are often a major limiting factor in pepper production with incidence sometimes near 100% and yield reduction up to 70% (2). Several plant viruses have been reported to naturally infect pepper in the USA and Caribbean basin including cucumber mosaic virus (CMV), pepper mottle virus (PepMV), potato virus X (PVX), potato virus Y (PVY), tobacco etch virus (TEV), and tomato spotted wilt virus (TSWV) (1, 3, 8-11, 14, 16, 18-20). Epidemics in most pepper growing areas have been well documented, with TEV and PVY reported to be the most prevalent (1, 3, 6, 10, 13, 19). Often these viruses are difficult to control, and although stylet oils, plastic mulch, and sticky traps have been used with limited success against the insect vectors, resistance is the control measure of choice. Resistance or tolerance to virus diseases of pepper have been reported (4, 6, 7, 17, 21); however, more resistant lines are needed. The objective of this study was to identify new sources of resistance in pepper to CMV, PepMV, PVY, and TEV.

MATERIALS AND METHODS

In this study, over 250 lines of *Capsicum* spp. were tested for resistance to CMV-CA, PepMV-CA, PVY-0, and TEV-CA. For a complete list of cultivars and lines tested see Appendix A. Plants were grown in 72-cell float trays in the greenhouse and inoculated at the 2-4 leaf stage. Inoculum was prepared by macerating systemically infected leaves of *Capsicum annuum* L. with a mortar and pestle containing 0.03 M potassium phosphate buffer, pH 7.0. Tests were repeated once. Plants were evaluated for symptom expression 28-35 days post inoculation, and infections or non-infections confirmed by protein-A-sandwich enzyme-linked immunosorbent assay (PAS-ELISA) (5). Known positives (pepper tissue infected with CMV, PepMV, PVY or TEV) and negatives (healthy pepper tissue) samples were included in every plate. Wells containing PBS-Tween were used to calibrate the Bio Rad Model 3550 Microplate Reader (Bio Rad, Hercules, CA). Mean absorbance of the healthy control plus three standard deviations was used to establish the positive-negative threshold for each ELISA plate. Seeds were collected from resistant plants and the resulting plants retested as above except inoculations were performed at the cotyledon stage.

RESULTS

More than 40 lines or cultivars were resistant to one or more of the viruses in preliminary tests; however, several of these failed to show resistance when retested. Some of these lines had been reported previously to be resistant to one or more of the four viruses, such as 'PI 159225', 'PI 159236', 'Dempsey', and 'Avalar'. Twenty-two previously unreported lines or cultivars were resistant to one or more viruses when inoculated at the 2-4 leaf stage (Table 1), in that no symptoms were observed and no plants were positive for virus when tested with PAS-ELISA. Eleven lines were resistant to CMV, fifteen lines resistant to PepMV, sixteen were resistant to PVY, and ten were resistant to TEV (Table 1). Four lines ('Aji Brown', 'Mandi Red', 'PI 281415', and 'Yellow Boutique') were resistant to all four viruses tested. Three other lines were resistant to all three Potyviruses tested ('Aji Rojo', 'PI 152222', and 'PI 159246').

In the second set of experiments, only sixteen lines were resistant to any of the viruses when inoculated at the cotyledon stage (Table 2). Two lines ('PI 152222' and 'PI 159246') were resistant to all three Potyviruses. All but two lines ('Aji Brown' and 'Aji Rojo') were resistant to PVY. However, 'Aji Brown' and 'Aji Rojo' were resistant to both PepMV and TEV (Table 2).

DISCUSSION

Ponz and Bruening (15) define 'operational immunity' as "under defined conditions,... the non-host or operationally immune plant not only fails to develop symptoms but also fails to support an increase in virus titer above that introduced as inoculum". Clearly, operational immunity to these four plant viruses was evident in several lines. Furthermore, the operational immunity was age-related. Some pepper lines were non-hosts when inoculated at the 2-4 leaf stage, but were infected when inoculated at the cotyledon stage (Tables 1 and 2). There could be a number of reasons for this age-related difference in resistance, the most likely being the change in types of minor veins and number of plasmodesmata in young versus older tissue, and hence viral loading into the vascular system (12). That is not to say that reduced replication of the virions or gene silencing are not involved in the differential age-related resistance, but reduced phloem loading or unloading of the infectious entity seems more likely.

These pepper lines need to be evaluated further with more virus strains so that the breadth and mechanism of the operational immunity can be determined. This work adds several new sources of resistance from pepper against CMV, PepMV, PVY, and TEV. It also identifies over 200 lines of pepper that do not have resistance to these virus diseases.

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Table 1. Resistance of *Capsicum* spp. to Cucumber Mosaic Virus (CMV), Pepper Mottle Virus (PepMV), Potato Virus Y (PVY) and Tobacco Etch Virus (TEV) when inoculated at the 2-4 leaf stage.

Cultivar	CMV	PepMV	PVY	TEV
'Aji Brown'	R	R	R	R
Aji Rojo'	S	R	R	R
'Chapeu de Frade'	S	R	R	S
'Long Green Kashmir'	S	R	S	S
'Japones'	R	S	S	S
'Jalapeno x Serrano'	S	S	R	R
'Malaysian Orange'	R	R	R	S
'Mandi Red'	R	R	R	R
'Marconi Red'	R	S	S	S
'Moldova'	R	S	S	S
'Neopolitan'	S	R	R	S
'Numex Primavera'	R	S	R	R
'Pasilla'	R	R	S	S
'PI 152222'	S	R	R	R
'PI 152452'	S	R	S	S
'PI 159246'	S	R	R	R
'PI 188803'	S	S	R	S
'PI 215699'	S	S	R	R
'PI 281415'	R	R	R	R
'Rellano Chile'	S	R	R	S
'Suave Rojo'	R	R	R	S
'Yellow Boutique'	R	R	R	R

R = resistance S = susceptible

Table 2. Resistance of *Capsicum* spp. to Cucumber Mosaic Virus (CMV), Pepper Mottle Virus (PepMV), Potato Virus Y (PVY) and Tobacco Etch Virus (TEV) when inoculated at the cotyledon stage.

Cultivar	**CMV**	**PepMV**	**PVY**	**TEV**
'Aji Brown'	P	R	S	R
'Aji Rojo'	S	R	S	R
'Chapeu de Frade'	P	S	R	S
'Jalapeno x Serrano'	S	S	R	S
'Malaysian Orange'	S	S	R	S
'Mandi Red	S	S	R	S
'Neopolitan'	S	S	R	S
'Numex Primavera'	S	S	R	S
'PI 152222'	S	R	R	R
'PI 159246'	S	R	R	R
'PI 188803'	S	S	R	S
'PI 215699'	S	S	R	S
'PI 281415'	S	S	R	S
'Rellano Chile'	S	S	R	S
'Suave Rojo'	S	S	R	S
'Yellow Boutique'	S	S	R	S

R = resistance S = susceptible P = partial resistance

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GENETICS OF RESISTANCE AGAINST CUCUMBER MOSAIC VIRUS (CMV) IN HOT PEPPER (*Capsicum annuum* L.)

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Key words: *Capsicum annuum*, CMV, inheritance, resistance

Abstract

The genetic nature of cucumber mosaic virus (CMV) resistance was studied in three crosses, viz C1024 (resistance) x CA87067 (susceptible), C1024 x Chilli (susceptible), and C1034 (resistance) x CA87067. CMV resistance was controlled by nuclear, recessive simple gene. Broad and narrow sense heritability estimates were high.

Introduction

Cucumber mosaic virus (CMV) is one of the most prevalent and widespread virus infecting hot pepper (Duriat, 1996). In Indonesia, eradication of infected plants and insecticide application to control insect vectors in order to restrain CMV was known ineffective. This is because the virus has wide range of hosts (Palukaitis *et al.*, 1992) and insect vectors are always exist in the field. Therefore, planting of high-yielding and CMV resistance cultivars is the only effective and sustainable disease management strategy.

High-yielding and CMV resistance cultivar development can be accomplished through breeding programs which combine gene(s) controlling resistance against CMV into a high-yielding genotype. From the previous work, we identified several pepper accessions potential to be the sources of CMV resistance controlling gene(s) (Herison, *et al.*, 2003). The present study was conducted to understand the genetic nature of CMV resistance controlling genes in these accessions. This information would be of great importance in designing an effective breeding program for high-yielding and CMV resistance.

Material and Methods

Four genotypes were used in this study, they were accession C1024, C1034, CA87067, and Chilli. Accession C1024 and C1034, derived from PBC375 and KA-2 respectively, were advance breeding lines selected for CMV resistance. CA87067 was a CMV susceptible line carrying TMV resistance character. Chilli was a CMV susceptible line potentially high-yielding. The parents, F1, F1resprocal, BC1, BC2, and F2

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generations from the crosses of C1024 x CA87067, C1024 x Chilli and C1034 x CA87067 were evaluated for CMV resistance.

All seedlings of each generation were grown individually in 200 ml plastic pot containing sterilized potting mix. Seedlings were maintained in an insect proof glasshouse with 50% shading intensity. Source of CMV isolate, method of mechanical inoculation, and disease examination were similar to those of the previous works (Herison, *et al.*, 2003). The severity of symptoms were scored following the scoring after Dolores (1996). Plants were classified into resistant, intermediate susceptible, and susceptible reaction type, when their symptoms were scored 0, 1 – 3, and 4 –5, respectively.

The existence of maternal effect and magnitude of gene action were estimate by calculating the ratio potency after Petr and Frey (1966). The presence of major gene effect in governing resistance against CMV was identified through Shappiro and Wilk normality test on the frequency distribution of F2 generation. Significant deviation from the normal distribution of F2 generation was an indicator of the presence of major gene effect. To estimate the number of genes controlling CMV resistance, the observed number of each group of plants with resistance, intermediate susceptible, and susceptible reaction type within the F2 generation were tested for various genetic ratios by chi-square analysis. Heritability in Broad sense and narrow sense were estimated by the method after Allard (1960) and Warner (1952), respectively.

Result and Discussion

The mean severity of symptom of F1s was similar to that of their reciprocals in all crosses (Table 1). This result indicated that there was no maternal effects controlling the inheritance of CMV resistance. The mean severity of F1 populations was higher than the midparent values, and the mean severity of F2s were higher than those of F1s and inclined toward susceptible parents. In all crosses, the calculated ratio potency were negative. The results conformed to the conclusion of Singh and Thakur (1977) and Rusko and Csillery (1980) that the genetic nature of CMV resistance was under control of recessive genes. The frequency distribution of F2 population in all three crosses were significantly deviate from normal distribution. This suggested that there were major genes involved the expression of CMV resistance in all crosses.

In C1024 x CA87067 cross, F2 sample population consisting of 191 plants segregated for 8 plants with resistant (R) reaction types, 35 plants with intermediate susceptible (I) reaction types and 148 plants with susceptible (S) reaction type (Table 2). This segregation fit with a 1(R):3(I):12(S) ratio, indicating that in this cross there were two segregating major genes governing CMV resistance between C1024 and CA87067 with dominant epistatic gene action. In cross of C1024 x Chilli, 310 plants of F2 sample population segregated for 45 plants with resistant (R) reaction types, and 265 plants with susceptible (S) type reaction. This segregation fit with ratio of 9 (R) : 55 (S) indicating that in this cross there were three segregating genes between C1024 x Chilli. Involved in controlling CMV resistance with complex epistatic type of gene interaction. Meanwhile, in C1034 x CA87067 cross, an F2 sample population of 200 plants segregated for 35 plants with resistant (R) reaction types, to 165 plants with susceptible (S) type reaction. This segregation fit with a ratio of 3 (R) to 13 (S) indicating that there were two segregating genes between C1034 and CA87067 governing CMV resistance with epistatic type non-allelic interaction.

With regard to number of genes, the F2 population of C1024 x CA87067 cross supported the hypothesis of two segregating genes. Meanwhile, the segregated population of C1024 x Chilli cross support the three gene hypothesis. This result indicated that C1024 has at least 3 CMV resistance genes, and the CA87067 although it is very susceptible, it probably possessed at least one gene controlling resistance against CMV. Segregated F2 population of C1034 x CA87067 cross revealed that C1034 has at least 2 CMV resistance genes. Further study is needed whether one or all of the CMV resistance gene(s) of C1034 are similar to that of C1024.

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Table 1. Mean and standard error of scores, ratio potency, and heritability estimate in different crosses for CMV resistance in hot pepper

Generation	C1024 x CA87067	C1024 x Chilli	C1034 x CA87067
P1	0.00 ±0.00	0.00±0.00	0.20±0.13
P2	4.70±0.11	4.20±0.14	4.80±0.13
F1	3.20±0.13	2.60±0.16	4.10±0.18
F1r	3.10±0.13	0.70±0.48	4.20±0.20
Hp	-0.270	-0.73	3.40
h^2_{BS}	0.91	0.94	0.93
h^2_{NS}	0.67	0.77	0.79

P1=the first parent, P2 = the second parent, F1 = P1 x P2 , F1r = P2 x P1 (the reciprocal cross), Hp = ratio potency, h^2_{BS} = hertability in broad sense, and h^2_{NS} = heritability in narrow sense

Table 2. Segregation ratio of F2 for CMV resistance and chi-square test of population for resistant to susceptible reaction type

Cross	Observed			Expected			Ratio	χ^2	P
	R	I	S	R	I	S			
C1024 x CA87067	8	3	148	12	36	143	1:3:12	1.43	0.478
C1024 x Chilli	45		265	44		266	9:55	0.02	0.818
C1034 x CA87067	35		165	38		151	3:13		0.651

R = resistant, I = intermediate susceptible, and S = susceptible

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REACTION OF *CAPSICUM* GENOTYPES TO *OBUDA PEPPER VIRUS*, *TOBACCO MOSAIC VIRUS* AND *CUCUMBER MOSAIC VIRUS*

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Summary

In 2003 year, research on virus susceptibility and resistance of *Capsicum* genotypes has been continued. The objective of this year in this respect was to examine the reaction of 29 *Capsicum* genotypes to common strain of *Tobacco mosaic virus* (TMV-C/U1), *Obuda pepper virus* (ObPV), (syn.: Ob strain of *Tomato mosaic virus*, ToMV-Ob) and legume strain of *Cucumber mosaic virus* (CMV-U/246). Mechanically inoculated plants were symptomatologically tested for infections. Five weeks after inoculation the infected plants were tested by direct double-antibody sandwich ELISA (DAS ELISA) method. Test samples were considered susceptible to viruses if their extinction values exceeded three times than those of the healthy control ones. In order to confirm the results of symptomatology and serology, back inoculations were also carried out to *Nicotiana glutinosa, N. tabacum* 'Xanthi-nc' and *N. tabacum* 'Samsun'. Among the tested *Capsicum* genotypes one (VI-13=13/96 ii) to TMV-C/U1, and one [VI-91 (179) 47/87] to ObPV showed resistance. Neither local nor systemic symptoms on inoculated plants could be observed and results of DAS ELISA and back inoculation were also negative. Six genotypes [XII-a=542, XII-a=543, XII-a=407 French Perennial, XII-a=9/99 F_1 x (RR DH x 412/a CMVR), XII-a=15/99 F_1 x (413 x R12 DH x R KDH) BC_1 F_1, XII-a=4/99 F_2] were resistant to CMV-U/246. These genotypes could be used for resistance breeding to viruses.

Introduction

Among pathogens, viruses are one of the major limiting factors in successful pepper growing (Edwardson & Christie 1997, Gáborjányi et al. 1998a, b, Tiznado & Carrillo 2002). The extremely stable, mechanically transmissible *Tobamoviruses* are found to be the major problems under glasshouse and tunnels, while the dominance of the aphid-borne *Cucumo-, Poty-* and *Alfamoviruses* were demonstrated in the open field (Kiss 1996, Gáborjányi et al. 1997, Kálmán et al. 2000). The breeding program against *Tobamoviruses* started with the introgression of L genes into commercial pepper varieties and today almost all pepper varieties containing L^1 gene are resistant to *Tobacco mosaic virus* (TMV). Among *Tobamoviruses* a new one: *Obuda pepper virus* (ObPV) (syn: Ob strain of *Tomato mosaic virus* (ToMV-Ob) has been appeared in the 1980's, which has broken the resistance of pepper varieties, containing the L^1 gene (Tóbiás et al. 1982, Csilléry et al. 1983), and only introgression of L^3 gene ensures resistance to ObPV.

Response of different *Capsicum* species, varieties, hybrids and breeding lines to viruses has been intensively studied. Out of them new sources of resistance have been found which could be used for pepper growing and breeding for virus resistance (Horváth 1983, 1986a, b, c, Zatykó 1993, Green & Kim 1994, Fehér & Kristóf 1995, Gáborjányi et

al. 1997, Lane et al. 1997, Horváth et al. 2000, Reddick & Habera 2000, Kazinczi et al. 2001a,b).

The objective of this study was to examine the reaction of different *Capsicum* genotypes to economically important viruses.

Material and methods

Seeds of 29 *Capsicum* species, hybrids and breeding lines were sown in sterilized boxes in our virological glasshouse free from vectors. Pepper seedlings were planted in plastic pots (12 cm in diameter) containing a soil mixture of sand (pH 6.96, humus % 0.27) : peat (pH 6.78, humus % 9.98) in a ratio of 1:3. Twelve [V-33=507/G.R., V-33=507 1-13, V-33=507 VI-10-1 in, V-27=422, V-43=404, V-25=324, V-11=361 x 380, VI-73 (175) RK konstans in/1, 539 French Giant, VI-73 R12 kons. bet. 14.5 x 7.5 cm, VI-13=13/96 ii kiemelt 15 x 7 cm, 5/97 F_5], two [VI-73 in/1 (174), VI-91 (179) 47/87], and fifteen [XII-a=542 Csilléri, XII-a=543 Csilléri, XII-a=407 French Perennial USA, XII-a=417 Perennial India, XII-a=411/a (an. x frut.) CMVR 50 %, XII-a=412/a CMVR 100% frut. x perennial, XII-a=414 CMVR 50%, XII-a=9/99 F_1 x RR DH x 412/a CMVR, XII-a=15/99 F_1 x 413 x R12 DH x R KDH BC_1 F_1, XII-a=17/99 F_1 x 413 x RK x RK BC_1 F_1, XII-a=4/99 F_2, XII-a=V-30a F_2 18/98 F_2 x RK DH F_2 48/98, XII-a=V-30/b F_2 18/98 F_2 x RK F_2, XII-a=IX-9 32/97 F_3 414 x Csipke F_3, XII-a=IX-10 33/97 F_3 413 x RK F_3] genotypes were mechanically inoculated with TMV-C/U_1, ObPV and CMV-U/246, respectively. Seven plants at 6-8 leaf stages of each breeding materials were used for inoculation. Sörensen posphate buffer (pH 7.2) in the ratio of 1:1 was used for inoculation. The inoculated plants were symptomatologically tested for infection. Five weeks after inoculation the infected plants were tested using direct double-antibody sandwich ELISA (DAS ELISA) method (Clark & Adams 1977). Substrate absorbance (extinction values) were measured twenty minutes after adding the substrate at 405 nm wavelength on Labsystems Multiscan RC ELISA Reader. Test samples were considered susceptible to viruses if their extinction values exceeded three times than those of the healthy (negative) control ones. In order to confirm the results of symptomatology and serology, back inoculation was also carried out to *Nicotiana tabacum* 'Xanthi-nc' and *N. tabacum* 'Samsun' as indicator plants in those cases, where the samples on the basis of symptoms and serology proved resistant to virus infection.

Results and discussion

Among the tested *Capsicum* genotypes one (VI-13=13/96 ii) to TMV-C/U1, and one [VI-91 (179) 47/87] to ObPV showed resistance. Neither local nor systemic symptoms on inoculated plants could be observed and results of DAS ELISA and back inoculation were also negative. Six genotypes [XII-a=542, XII-a=543, XII-a=407 French Perennial, XII-a=9/99 F_1 x (RR DH x 412/a CMVR), XII-a=15/99 F_1 x (413 x R12 DH x R KDH) BC_1 F_1, XII-a=4/99 F_2] were resistant to CMV-U/246 (Table 1). These genotypes could be used for resistance breeding to viruses.

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Table 1. Reaction of *Capsicum* genotypes to viruses

Capsicum genotypes	Viruses	Local/systemic symptoms*	DAS ELISA (extinction values)	Back inoculation
V-33=507/G.R.	TMV-C/U1	Chl/Mo	0,594	
V-33=507 1-13 anyató	TMV-C/U1	Chl/Mo	0,529	
V-33=507 VI-10-1 i.n	TMV-C/U1	Chl/Mo	0,992	
V-27=422	TMV-C/U1	Chl/Mo	0,587	
V-43=404	TMV-C/U1	Chl/Mo	0,858	
V-25=324	TMV-C/U1	Chl/Mo	0,556	
V-11=361 x 380	TMV-C/U1	Chl/Mo	0,977	
VI-73 (175) RK konstans in/1	TMV-C/U1	Chl/Mo, Bli	0,396	+
539 French Giant	TMV-C/U1	Chl, ChlRi/Mo	1,042	
VI-73 R12 konst. bet. 14.5 x 7.5 cm	TMV-C/U1	Chl/Mo, Led, Bli	0,588	
VI-13=13/96 ii kiemelt 15 x 7 cm	TMV-C/U1	-/-	0,156	-
5/97 F_5	TMV-C/U1	Chl/Mo, Led	0,829	
VI-73 in/1 (174)	ToMV-Ob (syn.:ObPV)	Chl/Mo	0,444	
VI-91 (179) 47/87	ToMV-Ob (syn.:ObPV)	-/-	0,181	-
XII-a=542 Csilléri	CMV-U/246	-/-	0,302	-
XII-a=543 Csilléri	CMV-U/246	-/-	0,300	-
XII-a=407 French Perennial USA	CMV-U/246	-/-	0,247	-
XII -a=417 Perennial India	CMV-U/246	-/-	0,593	
XII-a=411/a (an x frut.) CMVR 50%	CMV-U/246	-/-	1,254	
XII-a=412/a CMVR 100% (frut x perennial)	CMV-U/246	-/-	1,727	
XII-a=414 CMVR 50%	CMV-U/246	-/-	1,994	
XII-a=9/99 F_1 x=(RR DH x 412/a CMVR)	CMV-U/246	-/-	0,246	-
XII-a=15/99 F_1 x (413 x R12 DH x R KDH) BC_1 F_1	CMV-U/246	-/-	0,218	-
XII-a=17/99 F_1 x 413 x RK x RK) BC_1 F_1	CMV-U/246	-/-	0,549	
XII-a=4/99 F_2	CMV-U/246	-/-	0,182	-
XII-a=V-30/a F_2 (18/98 F_2 x RK DH) F_2 48/98	CMV-U/246	-/-	1,216	
XII-a=V-30/b F_2 (18/98 F_2 x RK F_2)	CMV-U/246	-/-	2,558	
XII-a=IX-9 32/97 F_3 (414 x Csipke) F_3	CMV-U/246	-/-	0,667	
XII-a=IX-10 33/97 F_3 (413 x RK) F_3	CMV-U/246	-/-	0,888	

*Chl, chlorotic lesions; ChlRi, Chlorotic rings; Mo, mosaic; Bli, blistering; Led, leaf deformation; -, symptomless

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SCREENING OF SWEET PEPPER GERMPLASM FOR RESISTANCE TO BACTERIAL WILT (*Ralstonia solanacearum*).

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Abstract

A set of thirty genotypes of sweet pepper comprising exotic and indigenous collections were screened against bacterial wilt in the wilt sick plots maintained in the Experimental Farm of Dept. of Vegetable Science and Floriculture. Two genotypes, IHR – 546 and PBC 631, were found highly resistant to bacterial wilt; five genotypes vi:; Arka Gaurav, PBC 505, Cap B, Bestidon and Cap C were observed as moderately resistant and the remaining twenty three were moderately to highly susceptible. The studies indicated the presence of resistance genes and the same can be utilized in developing wilt resistant sweet pepper cultivars.

Introduction

Bacterial wilt in capsicum caused by *Ralstonia solanacearum* E.F. Smith has become a serious problem in India (Gowda *et al.*, 1974; Gopalkrishnan and Peter, 1991). The commercial varieties are susceptible to this disease and chemical control through treatment of soil is cumbersome and uneconomical (Madalageri *et al.*, 1983). That's why, breeding varieties for bacterial wilt resistance combined with high yields and acceptable quality is the present day need. Occurrence of this disease is associated with high temperature (above 32^0 C) and sufficient moisture in the soil. Yield losses up to 100% are reported in wilt prone areas (Wang *et al.* 1997). Keeping this in view an investigation was undertaken to test a wide range of germplasm collection of sweet pepper, with the objective that they can either be utilised directly for cultivation or to find out germplasm sources of resistance to bacterial wilt to be utilised in developing resistant cultivars.

Materials and Methods

A set of thirty genotypes of sweet pepper comprising exotic and indigenous genetic stock collections as well as a few commercial lines with good performance was planted in a completely randomised block design with three replications. The disease intensity was recorded under natural sick plots maintained at the vegetable experiment farm of the Department, under field conditions. The wilting of the susceptible check indicated the presence of virulent inoculum in the soil. Bacterial ooze test was carried out on all the wilted plants to confirm bacterial wilt. The disease rating was done as per the scale suggested by Mew and Ho (1976).

Resistant: < 20% wilting
Moderately resistant : 20 to 40% wilting
Moderately susceptible : 41 to 60% wilting
susceptible : > 60% wilting

Results and Discussion

The results indicated that the capsicum genotypes IHR-546 and PBC-631 were highly to bacterial wilt (Table 1). The lines Arka Gaurav, PBC 505, Cap B, Bastidon and Cap C were observed to be moderately resistant and remaining entries ranged from moderately susceptible to susceptible category. Other workers have also reported the resistance against bacterial wilt in sweet pepper(Matsunaga *et al.*, 1993 and Wang *et al.*, 1997).

The wilt resistant accession, IHR-546 was dark green fruited, compact growth habit with pungent fruits. Fruit length is about 6-7 cm. Genotypes PBC-631 had long paprika type fruits, light green coloured and sweet in taste. Lines Cap B and Cap C (moderately resistant) were having erect conical type of fruits. Bestidon had normal bell shaped fruits.

The present studies indicate that the resistant gene for bacterial wilt is available in the capsicum strains and same may be incorporated into otherwise suitable commercial cultivars. Therefore, a breeding programme involving genotypes viz., IHR-546 and PBC-631 can be envisaged to transfer bacterial wilt resistance in a single genotype coupled with high yield potential.

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Table.1 - Disease rating of *Capsicum annuum* genotypes.

S.No.	Name of the line	Number of the wilted plants	Number of the plants survived	Per cent incidence/Mortality %	Disease rating
1	IHR-546	2	41	4.81	**Resistant**
2.	California Wonder	35	3	91.42	
3	Yolo Wonder	35	0	100	
4.	Arka Mohini	27	15	64.68	
5	Arka Gaurav	15	33	31.25	Moderately resistant
6.	HS 201	29	30	49.15	
7.	HS 202	21	15	58.33	
8.	EC-143570	47	2	95.91	
9.	PBC-631	0	35	0.00	**Immune/Resistant**
10.	PBG-505	15	23	40.00	Moderately resistant
11.	EC-143567	52	0	100	
12.	EC-174852	41	6	87.23	
13.	EC-203602	44	8	84.61	
14.	EC-240610	15	25	37.50	
15.	EC-160093	29	12	70.73	
16.	EC-175959	47	2	95.91	
17.	EC-175963	27	15	64.68	
18.	EC-175965	39	8	82.97	
19.	EC-279074	42	4	91.30	
20.	EC-464483	43	7	86.00	
21.	Cap B	15	33	31.25	Moderately resistant
22.	Cap C	11	32	25.58	Moderately resistant
23.	Bharat	35	2	94.28	
24.	EC-464110	19	21	47.50	
25.	EC-464111	42	7	86.0	
26.	Bastidion	12	35	25.54	Moderately resistant
27.	Pusa Deepati	20	25	44.44	
28.	Marvel	17	21	44.73	
29.	EC-464113	25	16	60.93	
30.	EC-464117	17	18	48.57	

Table-2 - Classification of *Capsicum annuum* based on bacterial wilt incidence.

Reaction to wilt	Wilt incidence (%)	Number of accessions	Name of accessions/varieties
Resistant	20	2	IHR-546,PBG-631
Moderately resistant	20-40	5	Arka Gaurav, PBG-505,Cap B, Cap C. Bastidon
Moderately susceptible	40-60		
Susceptible	60		

Note:- Moderately susceptible and susceptible genotypes being of no consequence, not indicated in the last columns.

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A COMPARISON BETWEEN A DETACHED LEAF AND A WHOLE PLANT METHOD FOR SCREENING PHYTOPHTHORA FOLIAR BLIGHT RESISTANCE IN CHILE (*Capsicum annuum*)

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Summary

A key focus in many chile breeding programs is the development of cultivars resistant to Phytophthora foliar blight (*Phytophthora capsici*) has become a key focus in chile breeding programs. A detached leaf technique that reflects the whole plant genotype could reduce the assay time from 7-12 days to 3 days and require only a leaf instead of the whole plant. A detached leaf method was compared to the whole plant method, which is the common standard for screening foliar blight resistance in *Capsicum*. The detached leaf method could not produce results matching the existing whole plant screening method. Therefore, the detached leaf method may not be a suitable way to screen for foliar blight resistance in *Capsicum*.

Introduction

Phytophthora foliar blight of chile (*Capsicum annuum*) is a leading constraint to chile production worldwide. Fungicide applications have provided some means of controlling foliar blight (Ristaino and Parra, 1998). However, fungicide insensitive isolates are known and may limit their use (Lamour and Hausbeck, 2001). In addition, registered fungicides may be banned in the future due to concerns about possible detrimental environmental effects. Therefore, the use of resistant cultivars is a practical, environment friendly, long-term solution to effective control of disease.

The development of Phytophthora foliar blight resistant cultivars is of paramount need While no commercial varieties currently have foliar blight resistance. Screening of breeding population for resistance is a common activity of many breeding programs. The most widely used screening method for foliar blight is the method of Alcantara and Bosland (1994). This method is an effective way to select for resistant plants. The whole plant method requires greenhouse space and time to develop larger plants as compared to a detached leaf method. With the whole plant method, once a susceptible plant has become infected with the disease, it is very difficult to 'rescue' the same plant for further genetic study. A detached leaf method would allow for a plant breeder not only to record the plant's reaction to infection but also save the plant. In addition, with a detached leaf method, a breeder could screen an individual plant for resistance to multiple races of *P. capsicii* at a single time. Pae and Yoon (1993) compared detached leaves and shoots of chile to a whole plant method for screening *Phytophthora* resistance in chile. They used 10 cm long top shoots to screen for resistance to *Phytophthora*, but their test included additional wounding of the detached stem. Their results showed an earlier susceptible response for the five varieties tested as compared to the whole plant method. Varieties that were resistant in the whole plant method were susceptible

in the detached stem method. However, no correlation was run to determine if the same plant had similar responses to both methods.

Laboratory screening methods have been developed in the past for potato late blight (*Phytophthora infestans* (Mont.) de Bary). Dorrance and Inglis (1997) compared detached leaf method to field evaluations and greenhouse screening method for potato late blight and found that the detached leaf method was comparable to field evaluations and greenhouse screening methods. Goth and Keane (1996) also found late blight development in potato on the detached leaf was comparable to the whole plant reaction. The purpose of this investigation was to determine if a detached leaf method similar to that used for potato could be an efficient way to screen for *Phytophthora* foliar blight resistance in *Capsicum* and also to understand whether the detached leaf technique give the same result with the whole plant inoculation technique

Materials and Methods

Plant materials. A well known resistant landrace 'Criollo de Morales' (CM443), and a susceptible cultivar Early Jalapeno were used in the study. Seeds were sown into 12-pack cells placed in a plastic trays (Hummert International, Earth City, MO) filled with commercially prepared peat moss-vermiculite mixture (Peatlite, Scott-Sierra Horticultural Product Company, Marysville). The trays were placed on a heated plant propagation pad in the greenhouse at 27-28 °C and watered twice daily. The seedlings were transplanted into four inch pots at the 4 to 6 true leaf stage. The seedlings were fertilized with Osmocote (14N-4.2P-11.6K) as needed.

Inoculum preparation. The *P. capsicii* isolate PWB-24 was chosen in this study, because it is the most virulent isolate and has been routinely used in the breeding program at New Mexico State University. Inoculum was prepared as described by Alcantara and Bosland (1994)

Detached leaf inoculation. A plastic cavity seedling tray (Cat# 14-3122 Hummert International, Earth City, MO) was laid inside the display tray (Cat # 11-3305, Hummert International) containing one liter of distilled water. Two pieces of nylon netting clothes were placed on top of the seeding tray to create a leveled surface for the leaves. Each seedling was numbered to record the disease reaction of individual plants in detached leaf to the whole plant. One immature leaf was removed from each plant with an alcohol-sterilized scalpel and placed on the nylon netting facing adaxial side up. Each leaf was inoculated with 45 µl inoculum (about 1800 zoospores). The same plant used in the detached leaf method was also used for whole plant inoculation. The same lot and same concentration of inoculum solution was applied to the whole plant using a small sprayer. Each plant was sprayed to wet by the inoculum to ensure each plant has received enough inoculum. The trays containing the seedlings and detached leaves were placed inside a mist chamber (Alcantara and Bosland, 1994). The mist chamber had an air temperature of 27 to 30°C and a relative humidity of 70%. After 48 hours, the trays with whole plants were removed from the chamber and placed on a greenhouse bench whereas, the trays with detached leaves were retained in the mist chamber to avoid wilting of detached leaf. The detached leaf was scored as resistant (R), if no lesion developed and scored as susceptible (S) if water soaked lesion occurred 3 days after inoculation. For whole plant, the plant was scored as R, if the plant did not die or did not develop any lesion within a week after taking out from the mist chamber. A two-way table was generated to show agreement between whole plant and detached leaf technique for foliar blight resistance by the table statement of Proc Freq in SAS (SAS Institute, 2001).

Results

A total of 277 individual plants were screened for response to foliar blight in detached and in whole plant inoculation methods. The simple Kappa coefficient (K) for agreement analysis

significantly deviated from 0 indicating lack of agreement between these two methods ($p< 0.0001$). Out of 146 plants that were resistant in whole plant method, 42 developed lesions in detached leaf method (Table 1). On the other hand, out of 131 plants that were susceptible in whole plant method, 28 did not developed lesions in detached leaf method. Interestingly, out of 145 Criollo de Morales plants, all were resistant when screened by the whole plant method, but 41 plants developed symptoms (Table 2). Similarly, 131, out of 132 jalapeno plants developed lesions in the whole plant inoculation method, but 28 jalapeno plants failed to develop lesion in detached leaf method

Discussion

The detached leaf method did not agree with the whole plant method in determining the resistance to *P. capsicii* and therefore foliar blight resistance cannot be predicted by the detached leaf method in *Capsicum*. The detached leaf method gave contradictory resistance responses when compared to the whole plant method. It appears that the disease susceptibility increases when screened by detached leaf method compared to whole plant method. Twenty eight percent plants that were resistant in whole plant method developed lesions, whereas 23% of the susceptible plants failed to develop disease symptoms in the detached leaf method. Vivianne et al. (1999) found an increased rate of infection and breakdown of resistance to late blight in potato when screened by detached leaf method. Simons (1955) found that detached oat leaves were more susceptible to rust than whole plants. Rust fungi that were normally avirulent on intact leaves of oats resulted in susceptible responses with a detached leaf.

When the experiment was done in a closed or open box at 27 ^{0}C, there was an increase in susceptibility. Inoculation on abaxial or adaxial surface did not change the scoring results. The detached leaf method was replicated several times and the results were contradictory. This clearly indicates that the detached leaf method does not reflect the whole plant situation. In conclusion, the whole plant screening method developed by Alcantara and Bosland is still the best and most reliable method for screening *Phytophthora* blight of *Capsicum*.

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Table 1. Comparison between detached leaf method and whole plant inoculation method for screening foliar blight in *Capsicum*.

Whole Plant Method		Detached Leaf Method		
Disease Reaction	No of plants	Disease Reaction		Total plants
		Resistant	Susceptible	
Resistant	146	104	42	146
Susceptible	131	28	103	131
Total	277	132	145	277

Table 2. Results of comparison between detached leaf method and whole plant method in screening two varieties of *Capsicum* for foliar blight

Whole Plant Method			Detached Leaf Method		
Variety	Disease Reaction	No of plants	Resistant	Susceptible	Total
Crio de Morales	Resistant	145	104	41	145
	Susceptible	0	0	0	0
Jalapeno	Resistant	1	0	1	1
	Susceptible	131	28	103	131

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BIOCONTROL OF FRUIT ROT OF CAPSICUM USING ANTAGONISTIC MICROORGANISMS

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Introduction

Capsicum commonly called red pepper (*Capsicum annuum* var. longum) is a prominent summer vegetable and spice crop in India. It is grown in tropical and subtropical regions of the world. The impediment for its cultivation is the susceptibility to large number of fungal pathogens of which fruit rot caused by *Colletotrichum capsici* (Syd.) Butler and Bisby was most important. The loss was estimated at 30.7 per cent in Tamil Nadu (Sujathabai, 1992) and 20-60 per cent in Punjab and Haryana States of India (Bansal and Grover, 1969). Not much information is available on control of this disease using non-chemical methods particularly antagonistic microorganisms. The present investigation was carried out to test the efficacy of two antagonists (*Trichoderma viride* and *T. harzianum*) against nine isolates of *C. capsici*.

Materials and Methods

Fresh *Capsicum* fruits showing characteristic symptoms of fruit rot disease were collected from different locations of Haryana (India). Nine isolates of *C. capsici* pathogen were isolated from the samples (Table 1). The two antagonistic fungi viz., *T. viride* and *T. harzianum* obtained from the Department of Plant Pathology, CCS Haryana Agricultural University, Hisar were used in the studies. The response of different isolates towards two biocontrol agent was assayed by dual plate technique *in vitro* using oat meal agar medium. The medium inoculated with pathogen alone served as control. The inoculated plants were incubated at 28+1°C. The diameter of mycelial growth was measured when control plates showed the maximum growth. The inhibition per cent was calculated (Vincent, 1927).

Results and Discussion

The inhibition of *C. capsici* isolates by *T. viride* was significantly higher than *T. harzianum in vitro* (Table 2). Isolates CC-2 and CC-7 were most sensitive to *T. viride*. However, isolate CC-5 was least sensitive to both the bioagents. The isolate CC-3 was most sensitive to *T. harzianum*. Similar observations were recorded by Jeyalakshmi *et al.* (1998) who found maximum inhibition of *C. capsici* by *Saccharomyces cerevisiae* followed by *T. viride* and *T. harzianum*. However, Singh (1992) obtained the string inhibition of *C. falcatum* by *T. harzianum*.

It was concluded that in antagonistic activity against *C. capsici* isolates, *T. viride* had more inhibitory effect than *T. harzianum*. Isolates varied in their response to the inhibitory effect of *T. viride*, CC-2 and CC-7 being the most sensitive. *T. viride* being effective *in vitro* could be used in the field for the integrated management of *Capsicum* fruit rot.

Table 1. Collection of various isolates of *Colletotrichum capsici* from different locations in Haryana (India)

Isolates	*Capsicum* cultivars	Location
CC-1	'Sadabahar'	Gurgaon
CC-2	'Pusa Jawala'	Karnal
CC-3	'Kiran'	Jind
CC-4	'Local'	Rohtak
CC-5	'Local'	Bhiwani
CC-6	'Hisar Vijay'	Hisar
CC-7	'C-142'	Panipat
CC-8	'CH-1'	Fatehabad (Tohana)
CC-9	'Hiramoti'	Hisar (Hansi)

Table 2. Inhibition (%) of mycelial growth of *Colletotrichum capsici* isolates by two *Trichoderma* spp.

Isolates	Inhibition *		Mean
	T. viride	*T. harzianum*	
CC-1	51.69 (45.95)**	32.85 (34.61)	42.27 (40.28)
CC-2	66.67 (54.69)	28.43 (31.98)	47.55 (43.33)
CC-3	58.71 (49.99)	42.79 (42.46)	50.75 (46.28)
CC-4	41.78 (40.23)	35.21 (36.36)	38.49 (38.29)
CC-5	20.37 (26.78)	16.67 (24.04)	18.52 (25.41)
CC-6	33.78 (35.49)	21.33 (27.49)	27.55 (31.49)
CC-7	66.19 (54.43)	23.81 (29.15)	45.00 (41.79)
CC-8	54.17 (47.39)	31.25 (33.95)	42.71 (40.67)
CC-9	48.41 (44.08)	39.56 (38.91)	43.98 (41.49)
Mean	49.08 (44.33)	30.21 (33.21)	

*Each value is average of 3 replications.

**Figures within the parentheses are angular transformed values.

CD (P=0.05) Isolate (A)=1.82, Bioagent (B) =0.86, AxB =2.58

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CULTURAL AND PATHOGENIC VARIATIONS AMONG NINE ISOLATES OF *Colletotrichum capsici* CAUSING FRUIT ROT OF CAPSICUM

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Introduction

Fruit rot caused by *Colletotrichum capsici* (Syd.) Butler and Bisby is one of the economically important disease of *Capsicum*. The disease was first reported by Sydow (1913) from Madras (India). Later on it was reported by Chowdhury (1957) from Assam.Annually 20-60% of the crop is being destroyed in Punjab alone due to this disease (Bansal and Grover, 1969).

In plant pathogenic fungi, existence of variability is a well known phenomena. For any host pathogen system, the studies on variation helps in evolving a new cultivars resistant to disease in a new location. Presently information on existence and distribution of variants of *Colletotrichum capsici* in *Capsicum* growing areas of Haryana State is not known. Hence studies on cultural and pathogenic potentiality were carried out with nine isolates of *Colletotrichum capsici* obtained from different cultivars and locations of Haryana.

Materials and Methods

Capsicum having symptoms of fruit rot caused by *Colletotrichum capsici* were collected from important *Capsicum* growing districts of Haryana (India). Isolations were made from the affected portion of diseased fruits and the isolates were purified by the single spore method. Details of the isolates collected from different locations are summarized in Table 1.

For cultural studies, the fungus was grown on various synthetic and non-synthetic media and incubated at 28+1°C. The linear growth in each case was determined by taking average of colony diameter in two directions after 7 days of incubation.

For pathogenic variations, the red ripe fruits on 105 days old plants of four capsicum cultivars viz., 'Sadabahar', 'Hisar Vijay', 'Hisar Shakti' and local hybrid 'Kiran' were surface sterilized and incubated by pin prick method as described by Muthulakshmi (1990). By this method, the fruits were pricked with pins studder in cork borer and then incubated with spore suspension of different isolates (3×10^4 spore/ml) of the pathogen. Twenty-five fruits were inoculated with each isolates. Five replications were maintained. The length and breadth of the lesions produced by various isolates on four cultivars were measured after 15 days of inoculation. The percentage of diseased area of fruits were determined by the following formula:

$$\text{Percentage diseased area of fruits} : \frac{W_2}{W_1} \times 100$$

Where W_1 = Total area of fruits before inoculation
W_2 = Area of lesions in the infected fruits

The total area of healthy fruits was calculated by the following formula:

$2 \pi r L_1 + \pi r L_2$

r = Radius of the fruit region nearby petiole.
L_1 = Length of fruit in upper cylinder like part
L_2 = Length of cone like lower portion

For differentiation of the isolates on the basis of pathogenic potential, the following disease rating scale (Jeyalakshmi 1998) was used:

Fruit area affected	Disease grade
Healthy	0
1-5%	1
5.1 – 10%	2
10.1 – 25%	3
25.1 – 50%	4
> 50.1%	5

The disease ratings were then categorized into disease reaction on the basis of following scale:

Disease grade	Disease reaction
0 – 1	Resistant (R)
1.1 – 2	Moderately resistant (R^+)
2.1 – 3	Moderately susceptible (S')
3.1 – 4	Susceptible (S)
4.1 – 5	Highly susceptible (S^+)

Further to distinguish the isolates clearly, these are grouped into Resistant (R, R^+) and susceptible (S', S and S^+) categories.

Results and Discussion

All the isolates grew well on oat meal agar followed by Richard's agar (Table 2). In terms of variability, isolate CC-6 was distinctly different because of its slow rate of growth. There was no significant difference in the radial growth among the isolates CC-1, CC-2, CC-3, CC-4, CC-5 and CC-7. Isolate CC-9 was having significantly higher growth than CC-8 which had slightly faster growth than earlier isolates. This is in agreement with the works of Misra and Mahmood (1960), Misra and Dutta (1963), who reported that *Colletotrichum capsici* isolates grew best on Richard's and oat-meal agar medium.

Critical analysis of data on disease grade and disease reaction clearly indicated differential interaction between host genotypes and isolates of pathogen (Table 3). Results clearly indicates that the isolate CC-9 constituted a distinct group as it gave susceptible reaction on cultivars 'Sadabahar', 'Hisar Vijay', 'Hisar Shakti' and 'Kiran'. Isolate C-C8 could be differentiated from isolate CC-6 on the basis of their pathogenic behaviour. The isolate CC-8 had susceptible reaction on cultivars 'Sadabahar', 'Hisar Shakti' and 'Kiran'. However, the isolate CC-6 had susceptible reaction on cultivars 'Sadabahar', 'Hisar Vijay' and 'Kiran'. The remaining isolates viz., CC-1, CC-2, CC-3, CC-4, CC-5 and CC-7 exhibited resistant reaction on all the cultivars.

Based on reaction of two cultivars 'Hisar Vijay' and 'Hisar Shakti' all isolates were divided into four groups (Table 4). Isolate CC-9 constituted a distinct group as it gave susceptible reaction on both the cultivars. In second group CC-8 induced susceptible reaction on 'Hisar Shakti' and resistant on 'Hisar Vijay'. Whereas CC-6 gave susceptible reaction on 'Hisar Vijay' and resistant on 'Hisar Shakti' constituted third group. Isolates viz., CC-1, CC-2, CC-3, CC-4, CC-5 and CC-7 induced resistant reaction on all the cultivars constituted fourth group. Attempts have been made by some workers earlier to categorize the cultivars into different groups on the basis of their reaction to different isolates (Singh, 1970; Kumar and Mahmood, 1984; Jeyalakshmi and Seetharaman, 1999).

On the basis of above studies it was concluded that all the above isolates divided into four groups. These can be designated as Group I (isolate CC-9 having significantly higher growth and susceptible reaction on all four *Capsicum* cultivars), Group II (isolate CC-8 capable of producing susceptible reaction on cultivars 'Sadabahar', 'Hisar Shakti', 'Kiran' and resistant on 'Hisar Vijay'), Group III (CC-6 having slow rate of growth capable of producing susceptible reaction on cultivars 'Sadabahar', 'Hisar Vijay', 'Kiran' and resistant on 'Hisar Shakti' and Group IV (CC-1, CC-2, CC-3, CC-4, CC-5 and CC-7) incapable of producing susceptible reaction on all the four cultivars.

Table 1. Collection of various isolates of *C. capsici* from different locations in Haryana

Isolates	*Capsicum* cultivars	Location
CC-1	'Sadabahar'	Gurgaon
CC-2	'Pusa Jawala'	Karnal
CC-3	'Kiran'	Jind
CC-4	'Local'	Rohtak
CC-5	'Local'	Bhiwani
CC-6	'Hisar Vijay'	Hisar
CC-7	'C-142'	Panipat
CC-8	'CH-1'	Fatehabad (Tohana)
CC-9	'Hiramoti'	Hisar (Hansi)

Table 2. Growth of *Colletotrichum capsici* isolates on different solid media

Isolates	Radial growth (cm)*				
	Potato dextrose agar	Chilli agar	Oatmeal agar	Richard's agar	Mean
CC-1	5.65	5.60	7.23	6.41	6.22
CC-2	5.58	5.55	7.33	6.46	6.23
CC-3	5.56	5.56	7.21	6.45	6.20
CC-4	5.61	5.53	7.25	6.46	6.21
CC-5	5.61	5.61	7.21	6.50	6.23
CC-6	5.16	5.26	6.30	6.10	5.70
CC-7	5.65	5.51	7.21	6.33	6.17
CC-8	6.26	6.08	7.65	7.33	6.83
CC-9	7.16	6.40	8.20	7.75	7.37
Mean	5.80	5.68	7.29	6.64	

*Each value is average of 3 replications.

CD (P=0.05) Isolate (A) = 0.190, Medium (B) = 0.126, A x B = 0.380.

Table 3. Reaction of *Capsicum* cultivars to different *Colletotrichum capsici* isolates

Isolates	*Capsicum* Cultivars			
	'Sadabahar'	' Hisar Vijay'	'Hisar Shakti'	'Kiran'
CC-1	2.00 (R^+)	1.00 (R)	2.00 (R^+)	2.00 (R^+)
CC-2	1.00 (R)	1.00 (R)	1.00 (R)	1.00 (R)
CC-3	2.00 (R^+)	1.00 (R)	1.00 (R)	1.00 (R)
CC-4	1.00 (R)	1.00 (R)	1.00 (R)	2.00 (R^+)
CC-5	2.00 (R^+)	2.00 (R^+)	1.00 (R)	2.00 (R^+)
CC-6	4.00 (S)	3.33 ($S^/$)	2.00 (R^+)	4.00 (S)
CC-7	2.00 (R^+)	2.00 (R^+)	2.00 (R^+)	2.00 (R^+)
CC-8	4.00 (S)	1.00 (R)	3.00 (S)	3.00 ($S^/$)
CC-9	4.00 (S)	3.33 ($S^/$)	4.00 (S)	3.00 ($S^/$)

*Each value is average of 25 fruits. R = Resistant; R^+ = Moderately resistant; $S^/$ = Moderately susceptible; S = Susceptible; S^+ = Highly susceptible.

Table 4. Grouping of *Colletotrichum capsici* isolates on the basis of disease reaction on two *Capsicum* cultivars

Cultivars	Isolates								
	CC-1	CC-2	CC-3	CC-4	CC-5	CC-6	CC-7	CC-8	CC-9
'Hisar Vijay'	R	R	R	R	R	S	R	R	S
'Hisar Shakti'	R	R	R	R	R	R	R	S	S

R = Resistant reaction; S = Susceptible reaction.

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RANKING OF BRINJAL GENOTYPES USING SELECTION INDEX VALUES

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INTRODUCTION

Brinjal is an important solanaceous vegetable, which is quite high in nutritive value and is reported to have some medicinal properties also (Choudhary, 1976). The average productivity of brinjal in India is only 20 - 35 t / ha depending upon the variety (Veeraraghavathatham, 1998). Improvement in yield is possible through selection for desired characters. Selection index exploits correlation with several traits having high heritability and it combines information on all the characters associated with the yield and thus aids in indirect selection for the improvement of yield. Here the desirable genotypes are discriminated from the undesirable once, based on the combination of various characters.

MATERIALS AND METHODS

The twentyfive brinjal genotypes collected from different parts of the country were grown at a spacing of 60 x 75cm in randomised block design with three replications during 2000-2001 at College of Agriculture, Vellayani. The cultural and management practices as per the recommendations of KAU were followed throughout the experiment. Observations were recorded for each treatment from five randomly selected plants from each replication for yield per plant, days to first flowering, plant height, number of primary branches per plant, number of secondary branches per plant, number of fruits per plant, number of leaves per plant, fruit length, fruit girth, weight of fruit and number of harvests. The selection index developed by Smith (1937) using discriminant function of Fisher (1936) was used to discriminate the genotypes based on the above given characters.

RESULTS AND DISCUSSION

Discriminant function technique was adopted for the construction of selection index for yield using fruit yield per plant (X_1) and component characters viz., days to first flowering (X_2), plant height (X_3), number of primary branches per plant (X_4), number of secondary branches per plant (X_5), number of fruits per plant (X_6), number of leaves per plant (X_7), fruit length (X_8), fruit girth (X_9), weight of fruit (X_{10}) and number of harvests (X_{11}). The characters showed high association with yield and a valuable selection index for yield in this crop was obtained.

The selection index value for each genotype was determined using the formula,

$I = 0.3855\ X_1 + (-1.1855)\ X_2 + 2.3184\ X_3 + 2.0008\ X_4 + (-3.4503)\ X_5 + 8.7592\ X_6 + 0.9725\ X_7 + (-9.3873)\ X_8 + (-2.2539)\ X_9 + 3.2311\ X_{10} + 34.0147\ X_{11}$

The genotypes were ranked according to their selection index values. The selection indices along with the ranking of each genotype are presented in the table given below.

Table 1. Selection index values

Rank	Genotype	Selection Index
1	Pusa Purple Cluster (V18)	3294.7130
2	Pusa Kranti (V17)	3145.7740
3	Brinjal Suphal (V21)	2792.2190
4	Swetha (V1)	2719.6750
5	Venganoor Local (V16)	2597.6980
6	Neyyatinkara Local (V7)	2478.5400
7	Vellayani Local (V10)	2416.3240
8	Peringamala Local V13	2392.4360
9	Surya (V2)	2380.0780
10	Co – 2 (V3)	2340.4480
11	Poomkulam Local (V14)	2330.3430
12	Nedumangad Local –3(V6)	2063.7190
13	Palappur Local (V22)	1958.2710
14	Pachalloor Local (V15)	1920.7870
15	Nedumangad Local –2(V5)	1890.8410
16	Thikkodi Local (V9)	1856.0770
17	Arkakusumkar (V19)	1802.2830
18	Kuttalam Local (V20)	1760.4550
19	Manjarigota Local (V24)	1739.7730
20	Kalliyoor Local (V12)	1734.7350
21	Vellayani Local – 2(V11)	1718.5600
22	Nedumangad Local –1(V4)	1458.7440
23	Alapuzha Local (V8)	1229.6250
24	Brinjal Supriya (V23)	1131.9580
25	Pragathy (V25)	1012.7830

The highest index value was recorded by Pusa Purple Cluster followed by Pusa Kranti, Brinjal Suphal, Swetha and Venganoor local. These five top ranking genotypes were identified to be of genetically superior.

The twenty five brinjal genotypes were ranked according to their selection index values. Pusa Purple Cluster followed by Pusa Kranti, Brinjal Suphal, Swetha and Venganoor local recorded the highest index value. These five top ranking genotypes were identified to be genetically superior

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COMBINING ABILITY STUDIES FOR YIELD AND YIELD ATTRIBUTING TRAITS IN ROUND-FRUITED EGGPLANT (*SOLANUM MELONGENA L.*) UNDER TARAI CONDITION OF UTTARANCHAL, INDIA.

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INTRODUCTION:

In breeding of high yielding varieties of crop plants, the breeder is often faces with the problem of selecting appropriate parents and crosses. Combining ability analysis is one of the powerful tools available which give the estimates of combining ability effects and aids in selecting desirable parents and crosses for further exploitation. The present investigation therefore, was undertaken to identify the best combiner among the existing germplasm of different yield attributing characters in round-fruited eggplant (*Solanum melongena* L.) to facilitate the formulation of a sound breeding method.

MATERIALS AND METHODS:

The present investigation was carried out during autumn-winter season from 2001-03 at Vegetable Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar, U. S. Nagar (Uttaranchal), India. The University lies in south of the Shivalik range of Himalayas. It falls in humid sub-tropical zone locally known as "*Tarai*" situated at latitude of 29^0 N, longitude of 79.3^0 .The materials for the present investigation comprised of a diallel set of five genotypes along with the parents excluding reciprocals of eggplant. These five genotypes were agronomically and morphologically diverse. The genotypes were Pant Rituraj (PR), PB-60, PB-61, PB-62 and T-3. All these were evaluated to study the combining ability of nine characters viz. days to first flowering, plant height, fruit diameter, fruit length, number of marketable fruits per plant, total number of fruits per plant, weight of marketable fruits per plant, total weight of fruits per plant and early yield per plant. The combining ability estimates were calculated according to method-2, model-I of Griffing (1956).

RESULTS AND DISCUSSION:

The analysis of variance for combining ability revealed significant mean square for both gca and sca effects in most of the characters except plant height and weight of marketable fruits per plant for gca. This indicated the importance of both additive and non additive gene action for expression of heterosis. Dahiya *et al.* (1982); Varshney *et al* (1999) and Babu and Thirumurugan (2001) were also of the same opinion.

The relative effects for gca and sca were obtained for all the characters are presented in Table 2.1 and 2.2 respectively. For days to first flowering four parents namely PB-62, PB-60, PR and T-3 showed negative gca effects while PB-61 had positive gca values for this trait. Three crosses viz. PR×PB-62, PR×T-3 and PR× PB-61 showed significant negative sca effects for this character. It is important here that negative values for above character are an indication of earliness. For early yield per plant (yield from first two harvesting) which is related to first flowering, parents T-3, PR and PB-62 shown significant positive

gca effects while higher significant sca was found in the crosses PB-62× T-3, PR× PB-61, PR× PB-60 and PB-61× T-3 .I t can be noted here that the parents and crosses showed negative gca and sca respectively for days to first flowering give positive effects for early yield i.e. high early yielder.

The best gca effect for fruit length and fruit diameter were noted in PR and PB--62 while T-3 showed highest gca but in negative direction. The hybrids expressing significant sca effects for fruit length were PR ×PB-60, PB-60 ×T-3, PR× PB-61 and PB-61 ×PB-62.For fruit diameter crosses were PR× PB-61, PR×PB-60, PB-61× T-3 and PB-60× PB-62.Parent T-3 showed highly significant gca effect for total number of fruits per plant and the cross PB-62 ×T-3 showed highly significant sca effect for this character involving T-3 as one of the parents.

The best general combiners for total weight of fruits per plant i.e. yield per plant were T-3 and PB-62.Highest significant sca effect was found in the cross PB-62 ×T-3 followed by PR× PB-61, PB-60 ×T-3, PR× T-3 and PB-60× PB-61.

High gca effect of a parent is a function of breeding value and hence due to additive gene effect or additive×additive interaction effect which represent the fixable genetic components of variation. According to Gilbert (1967) the additive parental effects as measured by gca are of more practical use than non allelic interactions, for their exploitation in conventional breeding. It is clear from the results obtained that in majority of the crosses which showed the best sca effect, the parental lines involved were at least one of the three most outstanding (on the basis of gca effects) parental lines namely PB-62,T-3 and PR .The best sca for yield was PB-62× T-3 involving both the parents having high gca . Therefore, it can be suggested that it is possible to predict the best hybrid for yield from the gca of the parental lines, at least in this population.

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Table 1: Analysis of variance for general and specific combining ability

Source of variation	Degrees of freedom	Mean squares for various characters			
		Days to first flowering	Plant height	Fruit length	Fruit diameter
GCA	4	32.767**	18.191	3.002**	3.608**
SCA	10	4.374**	187.072**	0.565**	0.779**
Error	28	0.255	14.01	0.089	0.075

Contd...

Source of variation	Degrees of freedom	Mean squares for various characters				
		Number of marketable fruits per plant	Total number of fruits per plant	Weight of marketable fruits per plant	Total weight of fruits per plant	Early yield per plant
GCA	4	5.307**	13.664**	0.037	0.089**	0.021**
SCA	10	2.139**	1.84*	0.300**	0.383**	0.016**
Error	28	0.324	0.644	0.061	0.020	0.003

* Significant at 5 per cent level of significance
** Significant at 1 per cent level of significance

Table2.1: Estimates of general combining ability effects of parents for various characters

Parent	Days to first flowering	Early yield per plant	Plant height	Fruit length	Fruit diameter	Number of marketable fruits per plant	Total number of fruits per plant	Weight of marketable fruits per plant	Total weight of fruits per plant
PR	-0.67**	0.09**	-0.097	0.46**	0.44**	-0.28	-0.34	0.03	0.04
PB-60	-1.08**	-0.05	2.00	0.14	0.14	-0.14	-0.42	-0.06	-0.11
PB-61	3.81**	0.002	-1.51	0.17	0.14	-0.21	-0.71	-0.08	-0.12
PB-62	-1.54**	-0.03	-1.00	0.37*	0.52**	-0.84*	-0.99*	0.10*	0.15*
T-3	-0.61*	-0.10**	1.47	-1.15**	-1.25**	1.48**	2.46**	0.01	0.04
SE(gi)	0.17	0.02	1.27	0.10	0.09	0.19	0.27	0.04	0.05
SE (gi-gj)	0.27	0.03	2.00	0.16	0.15	0.30	0.43	0.07	0.08
CD at 5%	0.47	0.06	3.53		0.25	0.53	0.75	0.11	0.14
CD at 1%	0.78	0.09	9.20	0.46	0.41	0.87	1.27	0.18	0.23

Table2.2: Estimates of specific combining ability effects in cross combinations for various characters

Cross	Days to first flowering	Early yield per plant	Plant height	Fruit length	Fruit diameter	Number of market-able fruits per plant	Total number of fruits per plant	Weight of marketable fruits per plant	Total weight of fruits per plant
PR×PB-60	0.44	0.13*	2.46	0.79*	0.93**	-0.34	-0.28	0.18	0.24
PR×PB-61	-1.32*	0.15*	11.38**	0.69*	1.17**	1.37*	1.00	0.88**	0.93**
PR×PB-62	-3.03**	0.08	9.40*	0.29	0.42	1.32*	0.24	0.22	-0.07
PR×T-3	-2.86**	-.001	5.42	-0.79*	-0.98**	-0.82	-1.89*	-0.36**	0.60**
PB-60×PB-61	-0.84	-0.09	11.90**	-0.03	-1.43**	1.29*	0.75	-0.21	0.49**
PB-60×PB-62	1.18*	-0.08	6.66	0.14	0.62*	-0.02	-0.37	0.01	-0.08
PB-60×T-3	1.65**	0.04	8.52*	0.79*	-0.05	1.50*	0.72	0.37*	0.62**
PB-61×PB-62	1.03*	-0.13*	15.85**	0.68*	0.36	-0.01	-0.48	0.30*	0.25
PB-61×T-3	-0.77	0.11*	2.10	0.50	0.63*	0.49	0.40	0.23	0.20
PB-62×T-3	-1.95**	.17**	-3.41	-0.80*	0.24	1.86**	3.00**	0.70**	0.95**
SE_{ij}	0.44	0.05	3.27	0.26	0.24	0.50	0.70	0.11	0.12
SE (ij-ik)	0.66	0.72	4.90	0.39	0.36	0.75	1.05	0.17	0.19
SE (ij-kl)	0.60	0.65	4.47	0.36	0.33	0.68	0.96	0.15	0.17
CD at 5%	0.98	0.11	7.29	0.58	0.54	1.11	1.56	0.25	0.27
CD at 1%	1.39	0.16	10.37	0.82	0.76	1.59	2.21	0.34	0.38

* Significant at 5 per cent level of significance
** Significant at 1 per cent level of significance

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EVALUATION OF F_1 HYBRIDS OF BRINJAL (*Solanum melongena* L.) FOR YIELD AND QUALITY

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Introduction

Brinjal (*Solanum melongena* L.) fruits are widely consumed around the world and it holds a very important place in China, India and Japan in various culinary preparations. Though yield is an important factor, high yield coupled with nutritive values are the requirements of these days. The productivity of this crop is very low since most of the growers cultivate the local varieties of that region. Hence, first generation hybrids can be cultivated to exploit the high yield and productivity. While selecting the F_1 hybrids of brinjal with high yield the quality factors is also to be considered. Hence a study was undertaken to observe the yield and quality factors among the different F_1 hybrids of brinjal.

Materials and methods

The investigation was carried out at Horticultural college and research institute, Tamil Nadu Agricultural University, Coimbatore with twenty five F_1 hybrids collected from diverse sources like SAU's, ICAR institutes and private seed companies. The field experiments with hybrids were laid out in a randomized block design with two replications during November, 2002. The soil of experimental field was sandy loam with a pH of 7.5. Thirty days old seedlings were transplanted on the ridges adopting a spacing of 60 X 45 cm. Standard horticultural practices and plant protection measures recommended for hybrid eggplant were adopted uniformly. Observations were made on characters like fruit length, fruit girth, number of fruits per plant, fruit weight, fruit yield, marketable fruit yield per plant, dry matter content and ascorbic acid content. The fruits were harvested at edible stage from the two replications under each hybrid and uniformly matured fruits were analysed for dry matter content and ascorbic acid content. The dry matter content was determined by drying of the samples at 60 degree celcious for 72 hours, from the recorded values the percentage of dry matter was calculated (Ahmed *et al.* 1999). Ascorbic acid content was estimated by volumetric method suggested by Sadasivam and Manickam (1992). Statistical analysis of data was done to estimate the *per se* values and their degree of significance of different traits.

Results and discussion

In the present study, brinjal hybrids exhibited significant differences for all the characters for growth, yield and quality parameters, thus offering

scope for selecting the high yielding hybrids accompanied with good quality fruits. The results are presented in Table 1. Fruit length is an important character to be considered to select a brinjal hybrid exhibiting high yield indirectly. Longer fruits were observed in the hybrids ARBH-785, PK-123 and DBHL-14. Similar observations were reported in brinjal hybrids by Jansirani (2000), Ananthalakshmi (2001) and Preneetha (2002).

Generally greater fruit girth was recorded in the round type fruits and lesser fruit girth in the long type fruits in the hybrids. Among the 25 hybrids the fruit girth was the highest in KBHR-3 followed by VRBHR-1. The hybrid COBH-1 was the best performing hybrid among the twenty five hybrids in terms of fruit yield per plant. The hybrids MHB-39, IVBHL-54 and Pusa Hybrid-5 also recorded satisfactory mean values for number of fruits per plant. Similar trend of higher number of fruits in F_1 hybrids were reported by Preneetha (2002).

The highest fruit weight was recorded by the hybrid, Mahadeva. The other hybrids with high fruit weight were recorded by ARBH-884 and VNR-125. In respect of fruit yield per plant the hybrids DBHL-14 and COBH-1 excelled all other hybrids. The hybrids Pusa Hybrid-5, ARBH-785, VNR-125, PK-123, VNR-51, IVBHL-54 and KBHL-3 also recorded the fruit yield of more than three kg per plant. The higher yield recorded by the hybrid COBH-1 might be due to the presence of the highest number of fruits per plant in the present study.

A brinjal fruit without the fruit borer holes decides the consumer preference, good quality and ultimately lead to the higher profit. The hybrid COBH-1 was the best performer registering the highest marketable fruit yield. The hybrids KBHL-3, ARBH-785 and Pusa Hybrid-5 recorded marketable fruit yield of more than two kilograms per plant. The above results of high marketable fruit yield in the hybrids are in line with the findings of Singh *et al.* (1988) and Preneetha (2002).

For processing, the brinjal hybrids with high dry matter content are desirable to get a good recovery in terms of quantity as suggested by Bajaj *et al.* (1981). In the present study among the twenty five hybrids, ARBH-785 and KBHL-3 recorded the highest dry matter content of 5.99 per cent. The hybrids Pusa Hybrid-5, COBH-1, DBHL-14, IVBHL-54 and PK-123 were also found to be better for this trait. Singh *et al.* (1988), Jansirani (2000) and Preneetha (2002) also observed higher dry matter content of brinjal fruits in their study. High dry matter content of brinjal fruits exhibited by the hybrids might be due to more fruit weight and long type fruits. These hybrids probably because of their better photosynthetic efficiency, partitioning efficiency as well as translocational efficiency could have accumulated more dry matter into economic part namely the developing fruits (Jansirani, 2000).

Generally, the higher ascorbic acid content would increase the nutritive value of the fruits, which would help better retention of colour and flavour. The hybrids COBH-1, ARBH-785, DBHL-14, KBHL-3, PK-123 and IVBHL-54 recorded higher ascorbic acid content. Jansirani (2000) also observed more ascorbic acid content in the hybrids in their studies.

Conclusion

The evaluation of hybrids based on the *per se* performance revealed that the hybrid COBH-1 performed better for important characters *viz.*, number of fruits per plant, marketable fruit yield and ascorbic acid. It is the only hybrid which recorded the highest marketable fruit yield per plant and maximum number of fruits coupled with the highest ascorbic acid content that is in need to meet out the main objective of the study. The other hybrids in respect of the highest marketable fruit yield coupled with good quality in terms of ascorbic acid content and dry matter content were KBHL-3, ARBH-785, Pusa Hybrid-5, DBHL-14, IVBHL-54, PK-123, Pusa Hybrid-6 and VNR-125 based on their ranking. These identified hybrids can be recommended for exploitation of their high fruit yield with good quality.

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Table 1. Mean performance of F_1 hybrids of brinjal for yield and quality

Name of the hybrids	Fruit length (cm)	Fruit girth (cm)	Number of fruits plant^{-1}	Fruit weight (g)	Fruit yield plant^{-1} (kg)	Marketable fruit yield plant^{-1} (kg)	Dry matter content (%)	Ascorbic acid content (mg/100g)
SAU HYBRIDS								
COBH-1	9.59	13.81	53.93	66.16	3.45	2.58	5.81	12.11
KBHL-3	14.80	12.75	38.10	79.23	3.00	2.33	5.99	10.82
KBHR-3	11.50	21.35	21.83	102.67	2.55	1.02	4.03	6.95
Phule Hybrid-2	7.95	18.95	21.75	73.73	1.88	0.82	3.01	4.37
ICAR HYBRIDS								
VRBHR-1	11.33	20.30	19.81	99.55	2.04	1.11	3.01	6.46
IVBHL-54	12.55	11.98	42.51	66.85	3.01	2.08	5.67	10.18
Pusa Hybrid -5	14.15	12.95	42.41	90.20	3.05	2.20	5.85	9.85
Pusa Hybrid -6	7.35	17.06	33.58	79.53	2.78	2.05	4.31	9.69
DBHL- 14	16.50	12.88	37.18	86.13	3.75	2.09	5.71	10.99
PRIVATE HYBRIDS								
ARBH- 201	10.30	14.50	36.50	72.20	2.90	1.02	4.47	6.14
ARBH- 785	17.73	11.98	40.13	71.92	3.05	2.31	5.99	11.15
ARBH- 884	13.31	16.23	25.51	117.75	2.69	1.03	4.53	7.60
Green Hybrid -1	7.56	12.95	27.98	56.85	2.25	0.99	4.18	7.76
EPH-100	11.40	20.18	22.78	103.88	2.02	1.10	4.06	6.46
EPH-168	10.12	14.91	33.21	66.31	2.94	1.64	4.01	6.79
Nun Br-014	11.82	18.98	20.51	99.17	1.80	1.16	3.13	7.76
Nun Br-015	12.41	15.53	20.15	84.60	1.63	1.43	4.03	7.43
Paras Kamini	15.17	15.58	19.85	93.17	1.71	1.03	3.51	5.65
Paras Kavya	13.39	15.85	20.95	65.57	1.72	1.01	3.43	6.30
VNR-51	11.19	12.98	40.92	65.45	3.01	1.80	4.27	7.60
VNR-125	13.76	12.98	30.69	108.00	3.02	1.98	4.19	9.85
Mahadeva	12.41	19.94	8.09	195.32	1.33	0.89	4.03	6.79
PK-123	17.08	15.95	33.05	94.17	3.02	2.15	5.03	10.51
MHB-10	8.09	18.47	33.18	69.70	2.63	1.16	3.79	9.37
MHB-39	4.28	11.41	47.09	59.93	2.24	1.36	3.21	7.92
SEd	**0.35**	**0.46**	**0.89**	**2.41**	**0.07**	**0.05**	**0.12**	**0.23**
CD(0.05)	**0.73**	**0.95**	**1.83**	**4.97**	**0.15**	**0.10**	**0.25**	**0.47**

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INFLUENCE OF BIOCHEMICAL FACTORS ON THE INCIDENCE OF SHOOT AND FRUIT BORER INFESTATION IN EGGPLANT

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INTRODUCTION

Eggplant (*Solanum melongena* L.) is a native of India and is extensively grown in all South-East Asian countries. It is one of the most important and popular vegetable crop grown round the year in most of the parts of India. The shoot and fruit borer (*Leucinodes orbonalis* Guen.) is the most serious pest of eggplant in India. As much as 70 per cent of the fruits have been reported to the damaged by larvae of this insect (Krishnaiah *et al.*, 1976). With the continuous use of insecticides for its control, it is feared that this insect may become resistant towards insecticides. Furthermore, the present control measurements are not fully effective and are also costly and hazardous. Hence, resistant varieties against this pest are urgently needed. Resistant may be due to physical, biochemical or both combined factors. Therefore, in the present study efforts were made to determine the biochemical factors of resistance in eggplant against shoot and fruit borer.

MATERIALS AND METHODS

The experiment comprised of 49 diverse genotypes of eggplant was laid out in randomized block design with four replications at Main Vegetable Research Station, Gujarat Agricultural University, Anand during 2001-2002 (September to February). There were natural insects and disease infestation in the field as no spraying was made to control it. Five random plants were selected from each plot for recording the observations on fruit borer infested fruits (%), while uniformly ripen fruits were collected at random from each plot to determine the biochemical composition. The fruits were cut and dry

matter was obtained by drying to a constant weight at 105° C. for six hours. The other biochemical factors like total phenols (Malik and Singh, 1980), total soluble as well as reducing sugars (Sadasivam and Manickam, 1992), Anthocyanin content (Ranganna, 1976), Polyphenoloxidase activity (Taneja and Sachar, 1974) and glycoalkloid content (Currie and Kuc, 1975) were estimated by using the standard procedures given by various scientists. Correlation and path analysis was worked out according to the method suggested by Wright (1921 and 1934).

RESULTS AND DISCUSSION

Character association and direct as well as indirect effects of biochemical factors on shoot and fruit borer infestation will provide precise information for the selection of important biochemical factors which may contribute more towards resistance to shoot and fruit borer. The data presented in Table 1 indicated that genotypic correlation of shoot and fruit borer infestation with total phenols, polyphenoloxidase activity and glycoalkloid content were negative and significant. However, this trait had positive and significant genotypic association with total soluble sugars, anthocyanin content and reducing sugars. The results are in agreement with the findings of Singh *et al.* (1982) and Bajaj *et al.* (1989).

The estimates of direct and indirect effects of biochemical factors on shoot and fruit borer infestation revealed that the total soluble sugars, reducing sugars and anthocyanin content had high positive and direct effect except anthocyanin content which have high indirect effect via total soluble sugars. This type of trend was also observed in reducing sugars which resulted into positive significant association ot these traits with shoot and fruit borer infestation. On the other hand, total phenols, polyphenoloxidase activity and glycoalkloid content had a high negative direct effect on shoot and fruit borer infestation.

It is suggested that the genotypes having high phenols, glycoalkloid and polyphenoloxidase activity and lower in total soluble sugar, reducing sugars and anthocyanin content could be utilized in the breeding programme for the development of shoot and fruit borer pest resistance varieties in eggplant crop.

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TABLE 1:

Path coefficient analysis sharing direct (underlined) and indirect effects of seven biochemical factors on shoot and fruit borer infestation in eggplant.

Characters	Dry matter (%)	Total phenols (mg/ 100mg dry wt.)	Total soluble sugars (mg/100mg dry wt.)	Reducing sugars (mg/100mg dry wt.)	Anthocyanin content (mg/100g)	Poly-phenol-oxidase activity (ΔOD per min.)	Glyco-alkaloid content (OD)	Genotypic correlation with shoot and fruit borer infestation
Dry matter	-0.0723	0.0829	-0.1450	-0.0525	-0.0011	-0.0041	-0.0199	-0.2102
Total phenols	0.0142	-0.4217	0.2093	0.1038	-0.0022	-0.0005	-0.0269	-0.4239**
Total soluble sugars	0.0144	-0.1209	0.7298	0.0976	0.0077	-0.0214	0.0277	0.7348**
Reducing sugars	0.0216	-0.2492	0.4056	0.1757	-0.0024	-0.0116	-0.0195	0.3202*
Anthocyanin content	0.0042	0.0495	0.2977	-0.0226	0.0188	-0.0315	0.0265	0.3426*
Poly phenoloxidase activity	-0.0026	-0.0018	0.13362	0.0177	0.0052	-0.2442	0.0840	-0.3483*
Glycoalkloid content	-0.0101	-0.0799	-0.1427	0.0241	-0.0035	0.0068	-0.1418	-0.3472*

*. ** Significant at 5% and 1% levels of significance, respectively.

RECIPES

Recipes in which pepper or its derivates are used follow. As usual they have been supplied by Terry Berke. Thank you, Terry.

Axoa Lamb with Espelette Pepper

In the Basque region of France, lamb tongue and hooves are used to further flavor the dish, but you may omit them if you like. The Espellette Harvest Festival is always the last weekend in October in Espellette, France. For more information, see http:\monpetitvillage.free.fr or email espelette.tourisme@wanadoo.fr

- ¼ cup olive oil
- 2 cloves garlic, chopped
- 2 red bell peppers, chopped
- 1 lamb tongue, cubed
- 1 1/2 cups beef bouillon
- 2 onions, chopped
- 4 green bell peppers, chopped
- 600 g lamb, cubed
- 2 lamb hooves, cleaned
- 2 bay leaves
- 2 Tb. Espelette powder (substitute hot paprika or chile powder)
- salt and pepper to taste

Saute onions and garlic in olive oil, then add bell peppers and saute until soft. Add lamb and saute for 5 minutes to brown the meat. Add Espelette powder, hooves, bouillon, and bay leaves, reduce heat, and simmer covered for 25 minutes. Salt and pepper to taste; serve with a crusty French bread and enjoy!
(from the August 2003 issue of Fiery Foods and Barbecue magazine)

Shatah (Jordanian Harissa Sauce)

This sauce is thought to be of Tunisian origin, but is found throughout all of North Africa and the Middle East under various names and spellings. It is used to flavor couscous and grilled dishes such as brochettes, and also as a relish with salads. Cover this sauce with a thin film of olive oil and it will keep up to a couple of months in the refrigerator.

* 10 dried whole red New Mexican chiles, stems and seeds removed
* Water
* 2 tablespoons olive oil
* 5 cloves garlic
* 1 teaspoon ground cumin
* 1 teaspoon ground cinnamon
* 1 teaspoon ground coriander
* 1 teaspoon ground caraway seeds

Cover the chiles with hot water and let them sit for 15 minutes until they soften. Place the chiles and remaining ingredients in a blender and puree until smooth using the chile water to thin it. The sauce should have the consistency of a thick paste.
Yield: 1 ½ cups. Heat Scale: Hot
(From http://www.fiery-foods.com/dave/jordan.asp)

The Stinking Rose's Garlic Salsa, from The Stinking Rose, a restaurant in San Francisco that features dishes loaded with garlic. Taxi drivers refuse to pick up their customers, says Dante Serafini, co-owner. "People leave here reeking", he admits with just a hint of pride.

- 3 ripe tomatoes, finely chopped
- 1 tablespoon chopped garlic
- 1 bunch cilantro, chopped
- 1/4 cup lime juice
- 1 onion, finely chopped
- 1 jalapeno, finely chopped
- 1 Tb. olive oil
- salt to taste

Combined all ingredients and let sit for 2 hours to blend the flavors, serve with tortilla chips.

Apicus de re Coquinaria, from Ovis Apalis, the West's oldest cookbook, written by Apicus sometime in the first century.

- 2 ounces pine nuts
- 1 tsp. Honey
- pinch of celery leaf
- 3 Tb. Vinegar
- pinch of black pepper
- 4 medium-boiled eggs (4 minutes)

Soak the pine nuts in the vinegar for 4 hours. Puree with all other ingredients (except eggs) in a blender. Serve sauce separate from eggs, and allow guests to add eggs according to taste.

Pakoras, from the Shikarbadi Hunting Lodge, Udaipur, India. A typical Indian snack food.

- 2 cups chickpea flour
- 1/2 tsp. Salt
- 1/2 tsp. baking powder
- peanut oil for frying
- 3/4 cup sliced onions
- 3/4 cup sliced eggplant
- 1 tsp. red chile powder
- 1/2 tsp. Turmeric
- water
- 3/4 cup sliced green chillies
- 3/4 cup sliced potatoes

Combine the flour, spices, and baking powder in a bowl. Add water and mix well until the batter has a creamy consistency. Heat the oil in a skillet until hot. Put the vegetables in the batter, drop them in the hot oil a few at a time, and cook until golden brown. Serve hot.

Spicy Raspberry Enema for Flatulence

There's even a capsicum remedy for this embarrassing condition. Unfortunately for herbal tea lovers, it is administered as an enema. Give the enema every four hours until the condition abates- and good luck.

- ½ cup raspberry leaves
- 1 teaspoon cayenne power
- ½ teaspoons valerian root, crushed
- 4 coups water
- 1 teaspoon lobelia leaf, crushed
- ½ teaspoon gum myrrh powder
- 1 teaspoon sugar

Add all the ingredients to a saucepan and bring to a boil. Turn off the head and allow to steep for 1 hour. Strain before using.

Kimchi, from the October 2002 issue of Chile Pepper magazine.

- 1 large napa (Chinese) cabbage
- 1/2 tsp. cayenne pepper
- 1/2 inch fresh ginger, grated
- 3 Tb. chopped fresh chile peppers
- 2 1/2 cups water
- 1/2 cup salt
- 2 cloves garlic, finely chopped
- 5 scallions, finely chopped
- 2 Tb. sugar

Layer cabbage in a large bowl and cover with salt, adding layers and covering with salt until reaching the top of the bowl. Cover with a snug-fitting lid or a weighted plate. Store in a cool place for 6 days. Remove lid and rinse cabbage under cold water. Mix with cayenne pepper, garlic, ginger, scallions, chiles, and sugar. Spoon mixture into an airtight jar, add water, seal lid, and store for 4 days or more (the longer the better). Remove lid, and eat with rice.

Pickled Lotus, from the October 2002 issue of Chile Pepper magazine.

- 2 cups rice wine vinegar
- 1/2 Tb. Sugar
- 1 bay leaf
- 1 large lotus root, peeled and cut into 6 mm disks
- 1/2 Tb. Salt
- 1 Tb. Turmeric
- 2 Thai bird chiles

In a small saucepan, combine the vinegar, salt, sugar, turmeric, bay leaf, and chiles and bring to a boil. Add lotus root and reduce heat to simmer for 20-30 minutes. Remove from heat and let stand until cool, then transfer to a jar with a lid and refrigerate overnight. Makes a great garnish for salsas.

Pepper magazine. This salsa won $25,000 in the 2001 International Chili Society's World Salsa Championship Cookoff (yes, there is such a thing) in Reno, Nevada.

- 10-12 firm tomatoes, finely diced
- 1 small can green chiles, diced
- 3 jalapeno peppers, diced
- 1 avocado, diced
- Salt and pepper to taste
- 1 medium white onion, diced
- 6 medium garlic cloves, diced
- 1 habanero pepper, diced
- Cilantro to taste

Mix all ingredients in a bowl; season to taste.

Barry Steinberg's World Champion Salsa, from the October 2002 issue of Chile Sardella (Poor Man's Caviar), from the October 2002 issue of Chile Pepper magazine. True sardella is made with sardine larvae, which isn't widely available. This recipe uses sardines and closely approximates the flavor of Sardella di Crucoli.

- 1/2 cup sardines
- 1/2 tsp. Fennel seeds
- 1 tsp. Paprika
- 1 1/2 tsp. dried peperoncino (substitute cayenne)
- ¼ cup roasted, peeled red bell pepper
- 1 Tb. olive oil

Grind fennel seeds into a powder. Rinse the sardines and place in food processor with the other ingredients. Process until smooth. Keep in a jar in refrigerator until ready to use. Great on bread or crackers, or as a pasta sauce.

Hooter's Buffalo Wings, by Robbie Haferkamp, from http://www.recipezaar.com/8590

- 1 cup flour
- 1/2 teaspoon cayenne pepper
- 20 chicken wings
- 1/2 cup Frank's Red Hot Sauce
- 1/4 teaspoon garlic powder
- 1 teaspoon salt
- 1/2 teaspoon paprika
- 1/2 cup butter or light butter
- 1/4 teaspoon black pepper

1. *Combine flour, salt, cayenne pepper, and paprika in bowl.*
2. *Coat chicken pieces in dry mixture.*
3. *Reserve leftover mixture.*
4. *Refrigerate coated chicken at least 1 hour.*
5. *Coat chicken in leftover flour mixture.*
6. *In a saucepan, heat butter, hot sauce, pepper, and garlic powder just until butter melts, then keep warm.*
7. *Deep fry chicken, 10 pieces at a time, in 375 degree oil for 13 minutes.*
8. *Drain chicken on paper towels.*
9. *Immediately place chicken in Tupperware bowl.*
10. *Pour half the hot sauce mixture over chicken (first 10 pieces).*
11. *Cover and toss to coat.*
12. *Repeat with second batch of chicken.*
13. *Wings can be frozen and reheated in 400 degree oven for 10 minutes.*
14. *NOTES : Use ranch or blue cheese dressing as a dip for these fabulous wings.*

Peacho de Gallo, a fruity twist on the popular Pico de Gallo recipe.
Source: Kim (They call me 'Spice Girl') Haines, Terry trusty assistant.

- 1 large onion, minced
- 4 Roma tomatoes, diced
- 1/4 cup minced cilantro
- 1 large peach, diced
- 4 jalapenos, seeded and diced
- 1 tsp lemon juice

Combine all ingredients and serve chilled. Good with corn or potato chips.

Nitir Kebe, a spiced butter that is an ingredient in many of Ethiopia's dishes. From Barbecue Inferno, Ten Speed Press, 2001

- 1 lb. unsalted butter
- 2 shallots, minced
- 1 Tb. grated ginger
- 1 tsp. Cinnamon
- 1 1/2 tsp. turmeric
- 1 Tb. crushed African bird peppers (substitute cayenne pepper)
- 2 cloves garlic, minced
- 1 tsp. Cloves
- 1 tsp. cardamom

Soften the butter and mix in the spices, refrigerate and use on bread or any dish where you would use butter.

PEPPER TRIVIA

Some new pieces of information and curiosities about pepper world, supplied by Terry Berke.

Espellette Peppers.... - The village of Espelette, France has an annual Celebration of Peppers the last Sunday in October. It now attracts more than 10,000 people and features food, music, dance, and games. Peppers were introduced there in 1523 by Gonzalo Percaztegi, the same year that corn first made its appearance there. At first it was thought to be related to black pepper (*Piper nigrum*) and was even called "long black American pepper". It wasn't until the 17th century that it was placed in its own genus. The name 'Espelette Pepper' received an Appellation d'Origine Controlee (AOC) from the National Institute for Trade Name Origins on December 1, 1999. This means no one else can sell peppers under this name, giving it the same protection as more famous products such as Champagne sparkling wine.
Source: 2001 Fiery Foods and Barbecue magazine

More than 300 police agencies around the U.S. have begun using the PepperBall SA200, a semi-automatic air rifle that fires marble-sized plastic balls that are filled with oleoresin capsicum in powder form. When the balls hit the target suspect, they explode, leaving a white cloud of noxious powder that incapacitates the unruly person. The PepperBall guns were used at the WTO riots in Seattle and at the Democratic National Convention protests in Los Angeles.
Source: Jaycor Tactical Systems of California, makers of the weapon.

Henry Ford (blcar.htm) invented the charcoal briquette in 1920 with the help of Thomas Edison (bledison.htm). Ford is the man who popularised the gas-powered car in America and invented the assembly line for automobile manufacturing. Ford created the briquette from the wood scraps and sawdust from his car factory. E.G. Kingsford bought the invention and put the charcoal briquette into commercial production. Kingsford charcoal is still a popular brand in the U.S. So next time you fire up your charcoal grill to grill some hot peppers, remember Henry Ford.

The ultimate Big Mac.....- A 20-ounce (560-gram) hamburger fashioned from ultra-tender Kobe beef debuted recently at the landmark Old Homestead restaurant. At $41, it is the most expensive hamburger in the city. It is the first time the 135-year-old steakhouse has ever put a burger on its menu. The restaurant bills it as "The World's Most Decadent Hamburger." "This is not about price," restaurant owner Marc Sherry said Friday, when the restaurant sold nearly 200 of the new burgers. "This is an event". Kobe beef, imported from Japan, comes from cattle raised on beer and massaged daily to make the meat soft and succulent. The burger, which has a piece of herb butter in the middle of each patty, comes on a special roll with exotic mushrooms and microgreens –shredded baby lettuce. Put away the bottled ketchup. The burger comes with a home-made ketchup, mustard, horseradish sauce, or chilli sauce. "And it's served," Sherry added, "with our classic garlic shoestring fries."
Source: http://www.cnn.com/2003/US/Northeast/01/11/offbeat.nyc.burger.ap/index.html

When Columbus set out from Spain his objective was to get King Ferdinand and Queen Isabella into the black pepper business. He believed that the islands he landed on in the Caribbean were off the coast of China. When the natives showed him chillies he decided to call them peppers and he had two good reasons. First, when it hit his tongue it felt like black pepper. Second and more importantly, he was getting paid to find "peppers" and so he did. Learn more about it on What We Eat TV, Episode 3: The Story of Chilli Peppers
Source: http://www.whatweeat.tv/epi_chili_peppers.html

The history of salsa.....- On a normal, volcano-erupting, saber-tooth-tiger-fleeing day, one of our hunter-gatherer relatives - let's call him Bobo - was nervously hunting/gathering through the cinder-spattered vegetation. After a hard day's work of stuffing on the run, his little leather satchel housed an over-ripe tomato, a charred piece of mastodon, a couple of dried chiles (pretty red decorations for a necklace, and a couple of rocks for throwing. Exhausted from scrounging and evading, Bobo needed a rest, so he bedded down for a rocky nap in the shelter of a narrow stone crevice. Using his furry fanny pack as a pillow, he slept restlessly, dreaming of narrowly escaping death by dinner. Upon awakening, Bobo was famished, so he reached into his rustic rucksack and gathered that piece of mastodon, now wet with the first-ever salsa. Seeing his scorched mastodon covered with this tomato concoction horrified Bobo. No one had ever sauced a main course before (France was still inhabited by Neanderthals). He cleaned the meat as well as he could and nibbled from one end. Kazow! He ran screaming for the nearest river, desperately attempting to extinguish this burning sensation. Bobo learned a hard lesson and he told all who would listen at every fireside chat never to mix mastodon with tomatoes. And so salsa died as quickly as it was whipped up.
Source: October 2002 issue of Chile Pepper magazine.

Along with goggles and gas masks, U.S. soldiers in Iraq are carrying another item into battle - mini bottles of Tabasco sauce in their food rations. In the 60's, McIlhenny Co. kicked up its efforts during the war in Vietnam. The armed forces stationed there received thousands of the Charley Ration Cookbook with recipes for jazzing up C rations with Tabasco

sauce, wrapped around bottles of the sauce in waterproof canisters. By the time Operation Desert Storm ended in 1991, Tabasco sauce had become a staple in the Meal Ready-to-Eat (MRE). Today, troops stationed around the world receive a bottle of the incendiary sauce, made simply of peppers, vinegar, and salt, with each MRE.
Source: Apr. 6, 2003 issue of Sacramento Bee newspaper

Researchers at New Mexico State University in Las Cruces, led by Dr. Clint Löest of the Department of Animal and Range Sciences, are exploring the possibilities of utilising the 15,000 tons of chile by-product (pods, skins, stems, and leaves) that are generated by growers and processors each year as cattle feed, particularly for dairy cattle. Research conducted by University scientists demonstrated that feeding dairy cattle an alfalfa-based diet including 20 percent chile byproducts (mostly pods and skins) did not have any large negative effects on milk constituents and appeared to increase total milk production. Interestingly, cattle not only will tolerate chile pods and byproducts, they actually seem to desire it. Dairy ranchers report cows rushing from all over the pens to feed on the chile byproducts when they are pitched into the feedlots. Such a love of chile contracts conventional wisdom that holds that capsaicin evolved to repel mammals. The cattle are not fazed by the heat of the pod waste, giving rise to a new ranching expression: a "chile-head of cattle." Whether or not the cows produce spicy milk has not been answered.....
Source: http://www.fiery-foods.com/whatsnew/indnews1102.asp#Cows%20Crave%20Chile%20B

One of the earliest recorded records of hot peppers is from an account by William Dampier (http://www.athenapub.com/damp1.htm) from "A New Voyage Round the World" (first published in London, 1697) dates from 1681, when he and his shipmates, including several Miskito Indians, landed on the south coast of Panama (then called Darien). He wrote about the Miskito: "Their Plantations are so small, that they cannot subsist with what they produce: for their largest Plantations have not above 20 or 30 Plantain Trees, a bed of Yams and Potatoes, a bush of Indian Pepper, and a small spot of Pine-apples; which last fruit is a main thing they delight in, for with these they make a sort of drink which our men call Pine-drink, much esteemed by these Moskito's, and to which they invite each other to be merry, providing Fish and Flesh also.
Source: http://www.athenapub.com/damp2.htm

Your tax dollars at work.....- Researchers at the Univ. of California-Berkeley have been mounting tiny cannons on the backs of cockroaches. This is correct: These researchers have been outfitting live cockroaches with backpacks containing plastic tubes filled with explosives. Of course, the researchers have a scientific reason for doing this: They are on LSD. No, really, it has something to do with figuring out how cockroaches have such good balance (Have you ever seen a cockroach fall off a bicycle?). The researchers used their findings to build a working robot roach the size of a toaster. Swell! If there's anything this world needs more than armed cockroaches, it's giant mechanised cockroaches! Newspaper story from 2004: "A homeowner in Santa Rosa was found shot to death in his kitchen Friday. Police said the man apparently was felled by 500 rounds of small-bore cannon fire, mostly in his ankles, indicating that this was the work of the gang of armed research cockroaches that escaped from a Berkeley lab. Police said the motive in the slaying was apparently a bottle of Tabasco sauce. In a related development, an escaped robot cockroach broke into an Oakland Wal-Mart and made off with an estimated 17,000 AA batteries". No wonder they call California "Land of the Fruits and Nuts"!
Source: Dave Barry, Miami Herald, Nov. 3, 2002

"The passion is raw, but the poultry is cooked!" shouted Richard Shea, wearing a pinstriped suit and straw hat, standing among 12 men wearing large white bibs. "10, 9, 8,...." At zero, the contestants dug into their aluminum trays, each piled high with 1.5 kg of chicken wings. The scene was The Back Page, a sports bar in New York City. The event was the first leg in the Frank's Red Hot Cayenne Pepper Sauce World Buffalo Wing Eating Circuit, a series that will conclude this month in -where else?-Buffalo, NY. The winner, Eric "Badlands" Booker, polished off 112 wings in 12 minutes and was declared Lord of the Wings.
Source: July 13, 2003 issue of Parade magazine.

On an August evening in A.D. 595, the Loma Caldera (in what is now El Salvador) erupted, sending clouds of volcanic ash into the Mayan agricultural village of Cerén, burying it twenty feet deep and turning it into the New World equivalent of Pompeii. Miraculously, all the villagers escaped, but what they left behind gives us a good idea of the life they led, the food they ate, and the chile peppers they grew.
Source: http://www.fiery-foods.com/dave/ceren.asp

There are over 100 different kinds of kimchi. It accompanies breakfast, lunch, and dinner in Korea, and Koreans claim to feel incomplete without a daily dose. Leafy green napa cabbage is the main ingredient, although radish, eggplant, cucumber, bellflower root, sesame leaf, ginseng, and crown daisies are often added, depending on the season. The laborious preparation and fermentation process makes it unbeatably healthy and (to Koreans, at least) so addictive.

ANALYTICAL INDEX

Pepper *(Capsicum spp)*

Eggplant *(Solanum spp)*